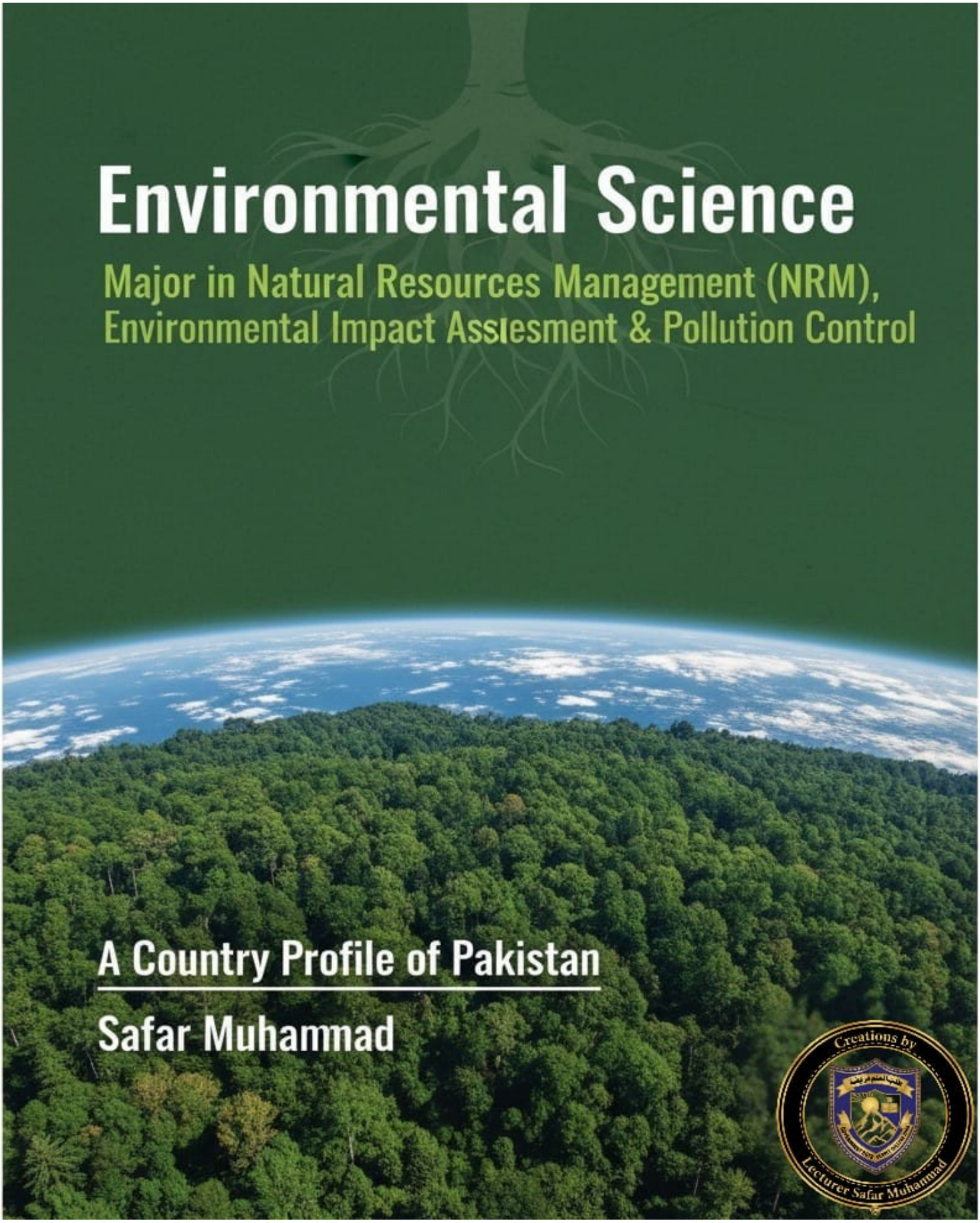
Environmental Science

Major in Natural Resources Management (NRM), Environmental Impact Assiesment & Pollution Control



A Country Profile of Pakistan

Safar Muhammad

Creations by
Lecturer Safar Muhammad

Environmental sciences: major in natural resource management (NRM), environmental impacts assessment (EIA) and pollution control.

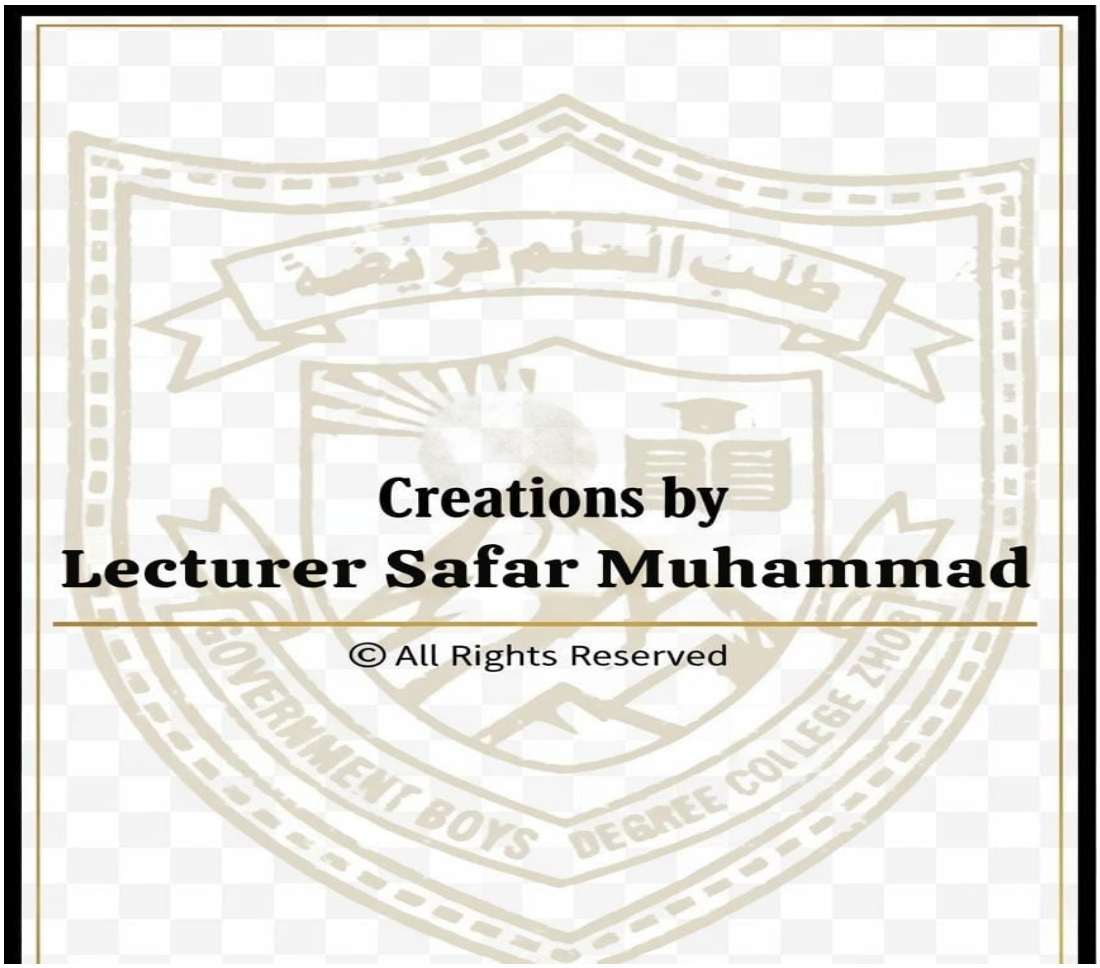
FIRST EDITION

SAFAR MUHAMMAD BABAR

Department of Environmental Sciences

Government boys' degree college Zhob Pakistan.

An affiliated college of the university of Balochistan (UOB) Quetta Balochistan.



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Preface to the 1st edition

This book is an academic book written according to the Pakistan higher education commission (HEC) Bachelor studies (BS) curriculum. The data is collected from all HEC recommended books and all other relevant books such **as environmental sciences by Tyler Miller & Scott E. Spool man (14th edition), "Earth as a living planet by Daniel B. Botkin & Edward A. Keller (8th edition) and textbook of environmental chemistry and pollution control by Dr. S.S Dara & Dr. D. D. Mishra, environmental engineering by Howard Peavy & Donald R. Rowe** are the few examples. This book is written for all BS enrolled students and for all competitive exams. The public service commissions (PSC) of all provinces in Pakistan also use same syllabus of HEC to carry their competitive examinations for different environmental related departments. purchasing all HEC recommended books for examinations preparation is the economic Burden, as the paper cost is rising day to day. This is my pleasure to write this book, from which the students get benefits. This is a collective and research-based data, which helps students and play the role of all recommended books in all types of examinations preparation.

Environmental sciences is a multidisciplinary field including environmental chemistry, economics, geology, geography, meteorology, ecology, marine sciences and biological sciences. Nowadays, it's very common subject and higher education commission has suggested this as a general paper in all disciplines. This book contains all major fields of environment such as natural resources management (NRM), environmental impacts assessment (EIA), pollution control, climate change, water quality, solid waste management, environmental policies, environmental laws and environmental chemistry. This book contains most recent data, as environmental sciences is the most emerging science with many discoveries. The world is facing many environmental challenges such as population growth, pollution, resources decline, climate change, ozone depletion and biodiversity loss. To overcome these challenges, global as well as regional and local scale laws and policies are adopted. To address the border scope of this subject, I had to write this book with long five-year research journey.

About the Author

Safar Muhammad Babar is an environmental, professional and researcher, who is currently serving as a **Lecturer in Environmental Sciences** at the *Government Boys Degree College*, District *Zhob*, Province of *Balochistan, Pakistan*. He obtained his **bachelor's degree in environmental sciences** from the *University of Peshawar*, Pakistan, where he developed a deep interest in environmental research, sustainable development, and ecological management.

Mr. Babar possesses a diverse range of professional experience in the field of environmental sciences. His areas of expertise include **water quality assessment, solid waste management, natural resource management, disaster risk management, sustainable development, environmental impact assessment (EIA), environmental sustainability, renewable energy**, and **biodiversity conservation**. His academic and professional journey reflects a strong commitment to addressing environmental challenges and promoting sustainable practices within both local and national contexts.

During his undergraduate studies, Mr. Babar worked with the **Pakistan Council of Scientific and Industrial Research (PCSIR)** on an environmental research project, where he gained valuable hands-on experience in laboratory analysis, environmental monitoring, and scientific reporting. Following his graduation, he contributed to the **Oil and Gas Development Company Limited (OGDCL)**, Pakistan, where he applied his academic knowledge to industrial environmental management. He also served as an **Environmentalist** with the **Balochistan Rural Support Program (BRSP)** for one year, actively participating in community-based environmental initiatives aimed at enhancing rural sustainability and resilience.

In his current role as a lecturer, Mr. Babar continues to inspire and educate students in the field of environmental sciences, emphasizing the importance of environmental protection, sustainable development, and climate change mitigation. His dedication to teaching and research is driven by his belief in empowering future generations to take responsibility for the environment through knowledge, innovation, and practical solutions.

The author expresses his heartfelt gratitude to **Mr. Hadiyatullah**, PhD Scholar in Environmental Sciences and GIS and remote sensing expert at the *University of Peshawar*, for his valuable cooperation, academic insights, and continuous support during the development of this book. Mr. Babar also acknowledges with deep appreciation the encouragement and assistance provided by his professional colleagues, friends, and the students of the *Government Boys Degree College, Zhob*, whose cooperation and motivation played a vital role throughout the research and writing process.

This book reflects **Safar Muhammad Babar's** passion for environmental education and sustainable development. It embodies his lifelong commitment to promoting ecological awareness, encouraging scientific inquiry, and contributing meaningful knowledge to the growing field of environmental sciences. Through this work, he aims to inspire students,

researchers, and policymakers to take collective action toward protecting the environment and ensuring a sustainable future for generations to come.

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GLOSSARY

CHAPTER 1 INTRODUCTION TO ENVIRONMENTAL SCIENCE

Environment stands for surroundings. The environment can be define as 'the sum of all conditions and influences that affect the development of an organism. It can also be define as "all the physical, chemical and biological activities which affect living things and non-living."

These definitions stress the totality of the environment, implying that every organism, including human beings, has its own environment. A few same terms have often been used for the environment. Synonyms include habitat, ecology, population-ecology, ecosystem, nutrient cycle, biodiversity, geosphere (zone of life) and ecosphere. In other words, the environment is an inseparable whole consisting of mutually interacting systems of physical and biological elements. The physical elements include space, landforms, water bodies, climate, drainage, rocks, soils, minerals, wealth etc. while the biological elements include man, fauna and flora, including micro-organisms. Experts recognize the following broad categories of environment:

CATEGORIES OF ENVIRONMENT

1. Physical Environment: mostly the Abiotic components of the environment include landforms, climate, water bodies, temperature, humidity, air etc.

2. Cultural Environment: The creations of man on the earth's surface are known as cultural environment or man-made environment.

3. Biological Environment: The biological environment consists of human beings, fauna, flora and micro-organisms.

4. Cognitive Environment or Subjective Environment (Mental Map): The perceived environment is known as cognitive or subjective environment. It differs from person to person. For example, atmospheric pollution has different meanings for a doctor, environmentalist, citizen, a villager and a farmer.

1: Components of environment

Environment has following biotic and abiotic components.

Biotic components	**Abiotic components**
Green plants, non-green plants, Decomposers, parasites, Symbionts, man.	Energy, radiation, Temperature, heat flow, water, air, fire, Gravity, topography, soil, geologic substratum.

:

SALIENT FEATURES OF ENVIRONMENT

The salient features of the environment are given below:

(i) At any given point of time, environment is the sum of biotic and abiotic elements.

(ii) Biodiversity, habitat and energy constitute the three basic components of the structure of an environment.

(iii) Environment changes in space and time.

(iv) It is based on the interactive and functional relationship between biotic and abiotic components.

(v) The working of an environment and its dependent systems are governed by the flow of energy.

(vi) Environment generates its own organic matter which differs in space, from region to region and climate to climate.

(vii) Environment tends to maintain an ecological balance within it`s carrying capacity.

INFLUENCE OF ENVIRONMENT ON MAN

Man, living both in the rural and urban settings all over the world, is directly and indirectly influenced by the factors of natural environment. Out of these factors, climate is one of the most important factors which have a close bearing on man's economic activities, decision making process about the use of resources and ultimately the culture and lifestyle of people. The direct impact of climate on different races can be seen on the color of skin, hairs, nose, cheeks, shape of head, stature, physical condition of body and overall physical appearance. Aristotle believed that there are some indirect impacts of environment. He said that "peoples of cold climates are brave but deficient in thought, while the peoples of warm climates are thoughtful but without courage."

The contrast view that there are some climatically ideal zones has been developed more recently by Ellsworth Huntington. According to his theory, the climates of areas in moderately cool zones with frequent cyclonic activity and rapid changes of weather (such as North-Western Europe, USA and Japan) stimulate individuals to mental activity and nations to world leadership. Some human geographers established a close relationship with the weather conditions and crimes like suicide, rape and murder. Some scholars have also attempted to measure the suitability of an environment of human activity, and his level of comfort and discomfort.

Man can modify the effects of weather and climate by creating artificial conditions. However, despite advancements in science and technology, man is still closely dependent on the physical environment for all his material needs such as food, clothing, shelter energy and water in the form of precipitation. The nature of this dependence, however, varies from people to people and region to region. The source of food and raw materials, however, remains the same for all groups. In fact, more than 50 percent of the labor force of the world is engaged in the primary economic activities such as agriculture, fishing, forestry, and mining, upon which the physical environment has great influence.

IMPACT OF MAN ON THE ENVIRONMENT

Environmental change is a continual process. It has been in operation since the Earth came into existence about 4.6 billion years ago. Since the origin of the Earth, the dynamic systems of energy and material have operated on a global scale to bring about gradual and sometimes catastrophic transformations in the atmosphere, hydrosphere, lithosphere, and biosphere. For most of the Earth's history, the agents of change have been the natural forces, like plate tectonics, volcanoes, earthquakes, cyclones, climatic change and natural elements of wind, ice, water, plants and animals. All these forces have interacted to produce dynamic ecosystems that both control and are controlled by each other. About four to five million years ago, Man, in fact, is considered by historians to be the most powerful agent of environmental change. Man is not the product of his physical environment, but he is the transformer and creator of his surroundings. In fact, human beings have been ecologically dominant since their emergence on Earth.

Man in other words has been interacting with his environment from the primeval stage of human development and continues to do so with even greater vigor in this age of space technology. With the advancement in science and technology, the frontiers of knowledge have expanded beyond cosmic space. The environment of the Earth has been transformed beyond recognition. People in their increasing number and technological skills have placed their imprints upon natural resources by 'transforming natural surroundings to fulfil their needs. In some instances, such as that of megacities and modern towns on land and seas, the human imprints may be so complete that the original landscape of nature has been totally wiped away and replaced by artificial and cultural environment.

The effect of the environment on man is modified, in part, the environment is perceived (cognitive one). Environmentalists distinguish this; that is the subjective environment from the objective environment (the real world as it is). The objective environment is of less importance to the individual than his or her perceived image of it. A division may also be made between the built environment and the social environment, which is made up of the various fields of economic, social, and political interactions. In many ways the distinction of the environment into physical and cultural environment is false, because the activities take place within the physical environment, and the physical environment is considerably affected by these activities. Modern environmental problems call for environmentalists to examine relations between Earth (environment/resources), society, and cultures throughout space and time. Critical environmental concerns that are integral to contemporary Physical environment include:

(i) Humans induced global warming.
(ii) Sea level rise and climatic change.
(iii) Global ozone depletion in the upper atmosphere that allows increasing amounts of ultraviolet radiation to reach Earth's surface.
(iv) Increasing air pollution, particularly in metropolitan areas.
(v) Natural hazards that threaten society, such as earthquakes, tsunamis, volcanoes, hurricanes, typhoons, surge, landslides, drought, and floods.

(vi) Over utilization of Earth's forests creates issues of deforestation and desertification.
(vii) Increasing losses of biodiversity and their habitat destruction.

FOUR SPHERES OF ENVIRONMENT

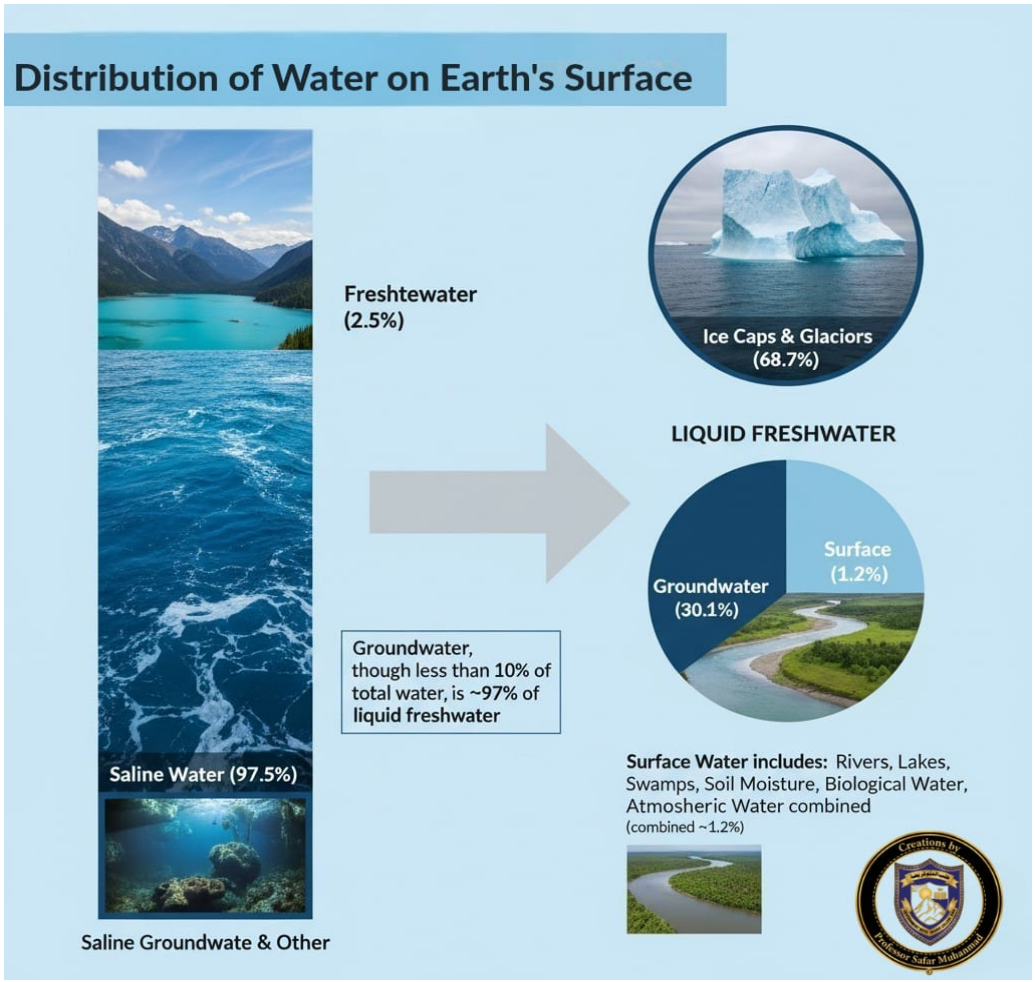
THE ATMOSPHERE

Earth is surrounded by a mixture of the most important gaseous envelope called the atmosphere. The atmosphere looks so high when we are observing a moving object but to compare the thickness (radius) of the solid Earth (about 6400 kilometers (4000 miles), the atmosphere is a very shallow layer. More than 99 percent of the atmosphere is within 30 kilometers (20 miles) of Earth's surface. This thin blanket of air is essential and life bears part of the planet. It not only provides the air we breathe but also acts to protect us from the dangerous radiation emitted by the Sun. This is because of the atmosphere that winds global circulation system exchanges the heat of tropics with poles and vice versa, so the global weather machine runs.

Unlike Venus (intense gases) and moon (no gases), earth's have a balanced gaseous atmosphere, which can hold an optimum temperature of 15 °C, without this greenhouse effect of earth's atmosphere, the temperature would be -18° C (a difference of 33 degrees) and earth's surface become inhabitable.

THE HYDROSPHERE

Earth is sometimes called the blue planet. More than anything else, water makes Earth unique. The hydrosphere is a dynamic mass that is continually on move, evaporating from the oceans to the atmosphere, precipitating to the land, and running back to the ocean again. The global ocean is certainly the most prominent feature of the hydrosphere, blanketing nearly 71 percent of Earth's surface to an average depth of about 3800 meters (12,500 feet). It accounts for about 97 percent of Earth's water. However, the hydrosphere also includes the freshwater found in clouds, streams, lakes, and glaciers, as well as that found underground. Although these later sources constitute just a tiny fraction of the total water resources, they are much more important than their percentage indicates. In addition to freshwater that is vital for life on land. Fresh water resources like streams, glaciers, and groundwater are responsible for creating many of our planet's varied landforms.



THE BIOSPHERE

The biosphere includes all biotic organisms on Earth. Oceanic life exits mostly in the sunlit surface waters of the sea. Most life on land is also concentrated near the earth's surface, with tree roots and burrowing animals reaching a few meters underground. Flying insects and birds reaching few kilometers in the atmosphere. A surprising variety of life-forms are also adapted to extreme environments. For example, on the ocean floor, where pressures are extreme and no light penetrates, there are places where vents spew hot, mineral-rich fluids that support communities of exotic life-forms. On land, some bacteria thrive in rocks as deep as 4 kilometers (2.5 miles) and in boiling hot springs. Moreover, air currents can carry microorganisms many kilometers into the atmosphere. But even when we consider these extremes, life still must be thought of as being confined to a narrow band very near Earth's surface. Plants and animals depend on the physical environment for the basics of life. However, organisms do more than just respond to their physical environment. Through countless interactions, life-forms help maintain and alter their physical environment. Without life, the makeup and nature of the geosphere, hydrosphere, and atmosphere would be very different.

THE GEOSPHERE

The geosphere is beneath the atmosphere and gives space to other spheres inside. The geosphere extends from the surface to the center of the planet, a depth of about 6400 kilometers (nearly 4000 miles), making it by far the largest of Earth's four spheres. The geosphere is divided into three different parts based on depth and composition: the dense inner sphere, called the core; the less dense mantle; and the crust, which is the light and very thin outer skin of Earth. Soil: thin layer rich of all nutrients support plants growth, may be thought as part of all four spheres. The solid portion is a mixture of weathered rock debris (geosphere) and humus from decayed plant and animal life (biosphere). The disintegrated rock debris is the product of weathering processes that require air (atmosphere) and water (hydrosphere). Air and water also occupy the open spaces between the solid particles.

CHAPTER2 APPLIED ECOLOGY

Ecology is a Greek word eco means house or home and logy means to study or discussion.

The scientific study of the interactions between organisms and their physical environment is known as ecology**.** Ecology examines the relationships between organisms belonging to both the same and different taxonomic groups and with their physical environment. This is the study of both terrestrial and aquatic environments and has different ecosystems. Ecology is a broad biological science which consists of many sub-disciplines.

BRANCHES OF ECOLOGY

BASED ON BIOME

Based on same environmental factors of a specific area in a given time period, the ecology has many branches such as Population ecology, behavioral ecology, quantitative ecology, qualitative ecology, human ecology, insect ecology and marine ecology.

Quantitative and qualitative ecology is the data derived in numerical values and also statistical treatment of new data.

Population ecology is the study of populations of different biotic components and their non-living components of an ecosystem in a biome.

Behavioral ecology this branch of ecology studies the behavior of individual to individual. because behavior can change with the interaction of environment or climatological factors. Some individuals are emotional, and others are calm. Behavior can be changes with rural natural and urban areas. Behavior is also linked with economic factors.

BASED ON REGION

Based on regional environmental conditions such as its severity and intensity, ecology have some following branches.

Benthic ecology

This is the study of benthos present at the bottom of a lake, which is a dark and oxygen deficient environment. Light cannot reach this region; this is why no autotropism takes place, and no rooted plants are present. Mostly decomposers are present.

Urban ecology

The study of the lifestyle of humans in a city, also study of different plants, animals and birds. Comparing the city in all aspects with rural areas.

BASED ON GEOGRAPHICAL LOCATION

On a global geographical scale, ecology has some broad branches such as.

Tropical ecology

The study of flora and fauna, particularly characteristics of fertile soil of region within 23 degrees north and south of the equator.

Tropical environments have characteristics of high humidity, heavy rainfalls, evergreen trees, slightly acidic soil, frost-free environment, decomposers and mineralization is very fast and minerals are always available in leaves to feed and make the plants evergreen.

Temperate ecology

The scientific study of highly changeable climatic zones and having four seasons in a year is called temperate ecology.

Arctic ecology

The study of the plants, animals and microorganisms of the region of the North Pole or nearer to this.

BASED ON SPATIAL SCALE

Micro ecology

Study of Small-scale Ecological phenomenon, for example ecological study of bacteria in participation of nitrogen cycling and the study remains to the part of bacteria.

Macro ecology

Large scale ecological phenomena. For example, variation of precipitation, variation of global temperature, vegetation process in different ecosystems.

Global ecology

Global ecological study comparing different environmental factors of the world biomes.

Landscape ecology

Different uses of land for different purposes based on ecological phenomena. Change in landscape conditions of different environments affect the ecological phenomena of different living organisms.

Applied ecology

The practices of employing principles and understandings to solve the problems of the real world. For example, the treatment of algal bloom in aquatic ecosystem.

Chemical ecology

Deals with the ecological roles of chemicals used in a wide range of areas including defense agents against predators. Poly cyclic aromatic hydrocarbons (PAHs) or pesticides degraded by bacteria or yeast. They cause practical degradation of these organic compounds, and they also synthesize chemicals inside their bodies.

Evolutionary ecology

This branch of ecology brings changes with environmental and climatic conditions through history.

Fire ecology

The role of fire in the environment of plants and animals and its effects on ecological communities e.g. forest fires.

Functional ecology

The specific niche of an organism in an ecosystem

Soil ecology

The ecological study of soil. It can be microorganisms and nutrients. Micro and macro-Nutrients are required for plant growth e.g. nitrogen, phosphorus and potassium.

System ecology

Utilizing different tools to predict the future of any ecological system.

LEVELS OF ORGANIZATION

The main levels of organization of ecology are six and are as follows**.**

Individual

An individual is an organism or living being that can act or function independently. It may be plant, animal, bacterium, fungi, etc. It is a body made up of organs, organelles, or other parts that work together to carry out the various processes of life.

Population

Population is a group of organisms or individuals usually of the same species, occupying a defined area during a specific time. Population growth rate is the percentage variation between the numbers of individuals in a population at two different times. Therefore, the population growth rate can be positive or negative. The main factors that make population increase are birth and immigration. The main factors that make population decrease are death and emigration.

There are some terms used for population

Natality

The number of individuals which add through reproduction in population is called natality.

In the case of human population, Natality is called **birth rate**, which is the number of individuals born per thousand per year.

Mortality

It is the opposite to natality. Define as “the number of individuals which decrease from population.

In human population, we called the mortality as **death rate,** which is the number of individuals died per thousand per year.

Immigration

The migration of a population inside an ecosystem /country.

Emigration

The migration from one ecosystem to another.

Doubling time

The time required for the population to be doubled.

Growth rate

When birth rate is greater than death rate, population rate is positive called growth rate. This is denoted by (r).

Special cases

If r= b-d = positive (+) or b>d then population will increase

If r=b-d= negative (-) or b< d then population will decrease

If r= b=d then no change in population will occur

Formulas

Growth rate= (birth rate-death rate) + (immigration-emigration)

Or r = (b-d) + (i-e)

Doubling time = average age÷ growth rate

Q: A tiger reserve has thousand (1000) population in which birth rate is 16 and death rate is 9, immigration is 1% and emigration 3%. calculating growth rate and doubling time? if the tiger supposed lifetime is 15 years and environmental factors

Ans: R = (b-d) + (i-e)

R= (16-9) + (1-3)

R= (7-2)

R=5%

R = 5%÷ 1000 × 1OO%

R= 0.5 %

Dt = 15÷ 0.5

Dt = 30 years

Q # 2: According to census2021, Pakistan has total population 231.4 million (231400000), death rate is 26.538 per thousand (6140893) and death rate is 7.17 per thousand (1659138). If emigration (to foreign countries) is 0.874 per thousand (202243.6) and immigration (to native country) is 0.461 per thousand (106675.4). What be the growth rate and doubling time if average age in Pakistan is taken 65 years.

Ans: R = (b-d) + (i-e)

R= (6140893- 1659138) + (106675.4-202243.6)

R= 4,481,755 – 95,567.6

R= 4386187.4

$$R = \frac{4386187.4 \times 100}{231400000}$$

R= 1.89%

Dt = 65÷ 1.89

dt = 34.3 years

Community

Groups of individuals of the same or different species interacting with their physical environment making a community. For example, a desert is an ecosystem containing many populations of cuticle plants, animals, and microbes interacting with high temperature, low moisture content and scarcity of water etc. A community is not fixed or rigid; communities may be large or small.

Types of Community

Based on size and degree of relative independence, communities may be divided into two types:

Major Community

These are large-sized, well organized and relatively independent. They depend only on the sun's energy from outside and are independent of the inputs and outputs from adjacent communities. E.g.: tropical evergreen forest in the North-East.

Minor Communities

These are dependent on neighboring communities and are often called societies. They are secondary aggregations within a major community and are not therefore completely independent units as far as energy and nutrient dynamics are concerned. E.g. A mat of lichen on a cow dung pad.

Structure of a community

In a community, the number of species and size of their population vary greatly. A community may have one or several species. The environmental factors determine the

characteristic of the community as well as the pattern of organization of the members in the community. The characteristic pattern of the community is termed as structure which is reflected in the roles played by various populations, their range, and the type of area they inhabit, the diversity of species in the community and the spectrum of interactions between them.

Organization pathway in ecology

Individual → population → community → ecosystem → biome → biosphere

ECOSYSTEM

An ecosystem is a structural and functional unit of biosphere consisting of communities of living beings and the physical environment, both interacting and exchanging materials between them. It includes plants, trees, animals, fish, birds, micro-organisms, water, moisture, soil, temperature, light, air and people. The Pakistan environmental protection act also define the ecosystem as "dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."

Ecosystems vary greatly in size and elements, but each of them is a functioning unit of nature. Everything that lives in an ecosystem is dependent on the other species and elements that are also part of that ecological community. It maintains itself naturally. If one part of an ecosystem is damaged or disappears, it has an impact on everything else. When an ecosystem is healthy (i.e. sustainable), it means that all elements live in balance and can reproduce themselves. The ecosystem can be as small as a single tree or as large as an entire forest.

5) Biome

A biome is a major ecological community having the same temperature, precipitation (same climatic zone) organisms (flora and fauna). Biomes consist of many ecosystems. For example, tropical rain forests, deserts and grassland.

The terrestrial part of the biosphere is divided into enormous regions called biomes, which are characterized by climate, vegetation, animal life and general soil type. No two biomes are alike. The climate determines the boundaries of a biome and abundance of plants and animals found in each of them.

Biosphere

Any part of all spheres which can hold living organisms or life is called biosphere.

BASIC ECOLOGICAL TERMS

Habitat

The physical environment in which an organism lives.

Niche (French word, to nest):

A niche is the unique functional, role or place of species in an ecosystem. It is the way an organism obtains and sustains the physical, chemical, and biological factors it needs to survive. An individual species must satisfy several needs in its niche. For example, the rabbits occur throughout Pakistan in habitats of desert and rangelands, their trophic niche are wild grasses, plant leaves and fruits throughout the year. They are living in protected caves and thorny shrubs. They also breed in their habitat, especially on elevated slopes.

An ecological niche consists of:

(i) Habitat– where the species live.

(ii) Food niche – what a species eats and decomposes and what species it competes with.

(iii) Reproductive niche – how and when it reproduces.

(iv) Physical and chemical niche – temperature, moisture, and landform.

(**v) Geo-ecological niche**– topography, terrain, slope, and soils etc.

Biota

The entire complement of species of organisms, plants and animals, found within a given region are known as biota.

Quadrate

Unit of quantification of ecology, which is used to count the species (plants and animals) in a particular area.

1 quadrate ⟶ 1 square meter

Productivity

The approximate rate of products which are obtained from photosynthesis during one year in an ecosystem is called its productivity.

Primary productivity

When plants convert sun's energy into food energy through photosynthesis.

Secondary productivity

When the energy flows from the first trophic level (producers) to second and third trophic level, then productivity is counted.

Community dynamics

Community dynamics are the changes in community structure and composition with time due to disastrous consequences like earthquakes, volcanoes, fires, and climate change.

Climax community

Climax community is associated with a particular climate and in a state of dynamic equilibrium with climate. This is the mature state of ecological succession.

Density

The number of individuals (biomass) per unit area per unit time is called ecosystem density.

Keystone species

The species that have a critical role to play in the maintenance of a specific ecosystem.

Each ecosystem has its own key stone species. For example, bison (grass eater) is a key stone species of grass land ecosystem. If this wild animal or alternative was not present in a fertile grassland, the fire would occur frequently, and the grass would burn.

Carrying capacity

The capacity or limit of the resources of an ecosystem beyond the utilization of which the ecosystem cannot hold or even be destroyed.

Carrying capacity is a concept related to sustainability. This can also be defined as:

The maximum number of individuals of species that can be sustained by an environment without decreasing the capacity of the environment to sustain that same number in the future.

Limiting factor

The limited amount of some essential of life available for organisms in an ecosystem.

Animal unit

A cow with his calf (450 kg) which eats 9.1 kg food for 24 hours is called an animal unit. Animal units are mostly used in natural resource management.

ECOSYSTEM TYPES

TERRESTRIAL ECOSYSTEM

Terrestrial ecosystems found widely in the world as well as in Pakistan, they are categorized as following.

BASED ON TOPOGRAPHY

Desert ecosystem

Desert ecosystems have different physical characteristics with associated flora and fauna. Their physical environment has a low annual precipitation of less than 10 milli meters, harsh climate linked with highest and lowest temperature, poor soil conditions with sand dunes.

This biome has fauna with hard covers to reduce evapotranspiration like cactus and other succulents to conserve water. The desert animals have specialized adaptations to conserve water and regulate body temperature such as camels, kangaroos and rats. The arthropods are adopted to burrow undergrounds to save themselves from scorching sand and to regulate their body temperature.

Plateau ecosystem

Plateaus are ecosystems of often high elevation related to flat or gentle sloping areas. They have unique communities of plants and animals adapted to local climate, topography and soil. Limited vegetation is due to harsh weather conditions, poor soil quality, limited water availability and high winds. Their species are highly vulnerable to climate change because of their specific features related to the geographic area. Globally important plateaus are Tibetan plateau, Colorado, Ethiopian and Andean of South America.

Mountain ecosystem

Mountains have rough topography, have a variety of biodiversity and their hotspots, have a great influence on daily weather, winds horizontal and vertical formation, and precipitation patterns. Mountains have great importance as they provide basins for water shed, support a range of flora and fauna, having forests as a sink to regulate climate as well as a source of recreation and tourism.

Unfortunately, these ecological sites have many threats in the form of climate change, habitat degradation, mining, deforestation and desertification. Many conservation efforts are taken worldwide by countries for compliance with their UN commitments in the form of protected areas, sustainable land-use planning and climate change mitigation and adaptation strategies.

Pakistan’s mountains are home to a rich and diverse range of biodiversity. The country’s mountainous regions include Hindu Kush, Karakoram and Himalayas. These mountains are the habitats of many iconic species such as Marco Polo sheep, Snow leopard, Himalayan brown bear. The mountainous area conservation fund (MACF) is a conservation effort to protect flora and fauna and promote sustainable development in the country’s mountainous regions.

BASED ON GEOGRAPHICAL LOCATION

Grassland ecosystem

The grasslands are temperate ecosystems that dominate grasses and other sparse herbaceous plants. They are found on every continent and cover about 20% of the Earth's surface.

They are characterized by low to moderate rainfall, temperate climate with warm summers and cold winters, fertile soil with rich humus and degrading microorganisms, dominated grasses with few trees and shrubs.

Different types of grasslands are found worldwide as follows:

Prairies: Found in North America, these grasslands are dominated by tall grass.

Steppes: Located in Eurasia, these grasslands are characterized by short grasses and shrubs.

Savannas: Found in Africa, Australia, and South America, these grasslands are a mix of grasses and scattered trees.

Pampas: Located in South America, these grasslands are known for their fertile soil and lush grass.

Tropical ecosystem

A tropical ecosystem is an environment characterized by hot, humid weather, typically located in the equatorial region between the Tropic of Cancer and the Tropic of Capricorn. Tropical rainforests ecosystems are distinguished by their consistent high temperatures exceeding 18 °C (64 °F) in a month and substantial annual rainfall. The abundant rainfall results in nutrient-poor leached soils, which profoundly affect the flora and fauna adapted to these conditions.

Tropical environments provide a wealth of natural resources to humans. Most of the global biodiversity is hosted in tropical areas such as tropical rainforest. The tropics are home to a wide variety of ecosystems that boast a great wealth of biodiversity, from exotic animal species to seldom-found flora. These forests are also called the lungs of the earth, contributing to the carbon cycle, with the ability to store 50% of carbon emissions as well as 40% of global oxygen turnover.

Studies in this area are mostly covered by scientists from Northern countries. The inclusion of scientists from countries where rainforest is present is heavily encouraged because it extends global knowledge and research which advances scientific contributions, benefiting tropical ecology.

However, despite the natural services provided by tropical ecology, deforestation is a threat to tropical rainforests. Any plant of interest can be exploited for commercial reasons and extraction of these specific plant species can be at a rapid rate without time for healthy regeneration.

Temperate ecosystem

A temperate ecosystem is an interacting system where a biological community and its non-living environments are found in regions with moderate climates, located between tropical and polar zones. These ecosystems have distinct seasons, typically with warm to hot

summers and cool to cold winters. Temperate ecosystems are characterized by obvious seasonality in temperature, with cooler winters and warmer summers, and also may show distinct seasonality in precipitation patterns, resulting from seasonal changes in the orientation of Earth's axis relative to the sun. Temperate zones are situated between the tropics and the polar regions, typically between 40° and 60° latitudes.

Global locations in the world can include Western Europe, western North America, and regions with a Mediterranean climate (like parts of the Mediterranean Sea, Western Asia, and parts of Southern Africa) are examples of areas with temperate ecosystems.

Polar ecosystems

A polar ecosystem is a complex of living organisms adapted to the harsh, cold conditions of the Arctic and Antarctic regions. These regions are characterized by extreme cold (-48 to -89˚C), limited sunlight and often frozen ground. Despite these harsh conditions, polar ecosystems are rich in biodiversity, supporting a variety of plant and animal life.

Polar habitats cover the top and bottom of planet-earth at the North and South Poles. The North Pole is surrounded by the Arctic Ocean. There isn't any land here, just a group of continually shifting ice sheets. Parts of Canada and Greenland are near the North Pole. The South Pole is located on Antarctica. This area has land, but it's completely covered with a layer of ice that's almost three miles thick in some places.

A polar ecosystem refers to a unique ecological region found in the Arctic and Antarctic continents, characterized by extreme climatic conditions, low temperatures, strong winds, and limited water availability. Polar bears and arctic foxes are adapted to the extreme weather of the Arctic region. Walruses and humpback whales live in the Arctic Ocean. Several kinds of penguins (including the emperor penguins) live in Antarctica and artic marine mammals like walruses and narwals. Animals like *caribou* or *musk oxen* may be so affected by periods of extreme weather that they become locally extinct.

Many bird species migrate to the Arctic during the breeding season including the Arctic tern known for its long migrations and various waders like the Dunlin and Red Knot, which experience significant population declines. Other notable migratory birds include the American Golden-Plover, Snow Geese, and Golden Eagles.

AQUATIC ECOSYSTEMS

FRESH WATER ECOSYSTEM

Fresh water ecosystems are classified as lotic (moving water) or lentic (still or stagnant water). Lotic water systems include freshwater rivers, streams, springs, rivulets, creeks, brooks, lakes, ponds and wetlands. Lentic water bodies include pools, ponds, some swamps, bogs and lakes. They vary considerably in physical, chemical and biological characteristics. Freshwater ecosystems are aquatic ecosystems characterized by low salt concentrations, typically less than 1%.

They are vital for biodiversity and provide numerous ecosystem services, including water purification, flood control, and food supplies. Freshwater ecosystems mitigate the effects of floods and drought such as coastal mangroves and riverbank vegetation protecting the land

from erosion and inundation. Wetlands and glaciers regulate water flows and aquifers can act as a storage buffer during dry spells.

Currently these ecosystems face many challenges than any other ecosystem of water bodies. The Freshwater species are going extinct more rapidly than terrestrial or marine species. Habitat loss and pollution are the most growing threat. Natural landscapes are being lost to urbanization, industry and agriculture. Due to Climate change, some areas are under flooding and increased rainfall can increase surface water areas. In some areas of the world lakes, wetlands and floodplains are drying up due to reduced precipitation and unsustainable management.

MARINE ECOSYSTEM

A marine ecosystem is an aquatic ecosystem with high salinity, encompassing a variety of habitats from coastlines to the deep sea. These ecosystems are characterized by high salt concentrations and support a diverse range of lifeforms, especially in shallow, tropical waters like coral reefs. Nearly three – quarter (1/3) of earth's surface is covered by ocean with an average depth of 3,750 m and with a salinity of 35 ppt, (parts per thousand), about 90 percent of which is sodium chloride.

Marine ecosystems are home to a host of different species ranging from planktonic organisms that form the base of the marine food web to large marine mammals. Many species rely on marine ecosystems for both food and shelter from predators. These habitats alone account for approximately 30% of all marine biological productivity. The diversity and productivity of this ecosystem is also important for humans. These habitats provide a rich source of food and income. They are very important to the overall health of both marine and terrestrial environments.
Despite the importance of marine ecosystems, increased human activities have caused significant damage and serious threats to the marine biodiversity. These activities can be overfishing, pollution, introduction of exotic species or coastal development. For this reason, conservation plans are necessary to save the marine ecosystems from being lost.

ESTUARIES

Coastal bays, river mouths and tidal marshes form the estuaries. In estuaries, fresh water from rivers meets ocean brackish water and the two are mixed by action of tides. Depending on its geological and climatic location, an estuary may include the following habitat types: salt marshes, mangroves, seagrass meadows, sandy beaches, rocky reefs, mudflats, sand flats, supratidal flats, shellfish beds, channels and tidal pools.
Estuaries are highly productive compared to the adjacent river or sea. Estuarine ecosystems play an important role in providing food, nesting area and breeding grounds for higher trophic levels such as migratory bird species and sea mammals. They can serve as nurseries for multiple fish and crustacean species. They also provide benefits to society, such as food production and recreation.
There are many challenges facing by estuaries. Stream and riverbanks can be damaged by erosion, outdated agricultural or forestry methods and construction too close to the stream.

Fish numbers then decline, because their nesting and feeding areas are destroyed. Dams, invasive species, and poor boating and fishing habits can cause even more damage.

Stormwater runoff carries contaminants from roads, vehicles, lawns, and construction from the land and pours it into the nearest stream. Outdated farming methods can also cause excess nutrients, sediment, and chemical pollution to end up in estuaries. Urban waterways and large agricultural regions concentrate runoffs and create toxic "hot spots" where nothing can live.

Estuaries are also highly sensitive to changing climate. Rising sea levels can inundate shallow coastal areas with seawater, disrupting the balance between fresh and salty water. Floods, storms, and other extreme weather events can change the amount of water flowing into an estuary from upstream, leading to more polluted runoff, erosion, and sedimentation.

CORAL REEFS

Coral reefs are underwater ecosystems formed by colonies of tiny marine animals called coral polyps. These reefs are often found in warm, shallow ocean waters, mainly in tropical and subtropical regions. They provide habitats for thousands of marine species, making them one of the most biodiverse ecosystems on Earth. Coral reefs also protect coastlines from erosion.

Coral reefs are some of the most diverse ecosystems in the world. Thousands of species of coral have been discovered; some live in warm, shallow, tropical seas and others in the cold, dark depths of the ocean. The diversity of life found in the habitats created by corals reefs are often called the "rainforests of the sea." About 25% of the ocean's fish depend on healthy coral reefs. Fish and other organisms' shelter, find food, reproduce, and rear their young in habitats formed by corals. Deep water reefs or mounds are less well known but also support a wide array of sea life in a comparatively barren world.

Shallow water, reef-building corals have a symbiotic relationship with photosynthetic algae while deep sea corals take food from plankton and organic matter for much of their energy needs. Coral reefs protect coastlines from storms and erosion, provide jobs for local communities and offer opportunities for recreation. They are also a source of food and medicines.

Coral reef ecosystems are severely threatened. Some threats are natural, such as diseases, predators, and storms. Other threats are anthropogenic, including pollution, sedimentation, unsustainable fishing practices, and climate change, which is raising ocean temperatures and causing ocean acidification. Many of these threats can stress corals, leading to death, while others cause physical damage to these delicate ecosystems.

The key global initiative and organizations to protect, conserve and restore the coral reefs are the global UN based fund for coral reefs (GFCR),The US coral restoration foundation, coral guardian, global coral reef alliance (GCRA), Coral reef alliance, reef ball foundation, reef check, green fins and international coral reef initiative (ICRI) and the most recent global action is coral reef rescue initiative (CRRI).

Global fund for coral reefs (GFCR) is a global public-private coalition dedicated to coral reef protection and restoration. It's also providing grants and a funding commitment of 25 million dollars to scale reef-resilience measures across multiple "reef nations". Coral Reef Rescue Initiative (CRRI) is union of about eleven countries and a global Programme launched in mid-2025. It aims to protect and regenerate tropical coral reefs that are rapidly degrading, through nature-based solutions. It is led by WWF (worldwide fund for nature) in collaboration with many conservation, scientific and development organizations. Among others, it is mainly financing by the global environment facility (GEF).

MANGROVES

Mangroves trees grow in areas with low-oxygen soil, where slow-moving waters allow fine sediments to accumulate. Mangrove forests only grow at tropical and subtropical latitudes near the equator because they cannot tolerate freezing temperatures. There are about 80 different species of mangrove trees. Many mangrove forests can be recognized by their dense tangle of prop roots that make the trees appear to be standing on stilts above the water. This tangle of roots allows the trees to handle the daily rise and fall of tides, which means that most mangroves get flooded at least twice per day. The roots also slow the movement of tidal waters, causing sediments to settle out of the water and build up the muddy bottom.

These forests have great importance as they play a crucial role in coastal protection. Mangrove forests stabilize the coastline, reducing erosion from storm surges, currents, waves and tides. The intricate root system of mangroves also makes these forests attractive to fish and other organisms seeking food and shelter from predators. Mangroves are unique and highly productive and have a great importance in biodiversity conservation. They are home to a wide variety of fish, reptiles such as sea turtles, land turtles, alligators, crocodiles, crocodiles, caimans, snakes, lizards and invertebrates such as shrimp, crabs, oysters, tunicates, sponges, snails and insects.

Currently, they face many challenges natural as well as anthropogenic. Natural calamities may include tsunamis and cyclones that have been causing a lot of damage. Anthropogenic Threats may include Clearing of these forests for agricultural purposes, human settlements and infrastructure and industrial areas. Environmental pollution leading to Climate change is the major threat for mangroves forests.

The mangrove breakthrough is a global initiative launched to protect, restore, and sustainably manage mangrove ecosystems around the world. They seek to mobilize $4 billion to protect and restore 15 million hectares of mangrove by 2030. Other major globally functional body for mangrove is the global mangrove alliance. It is a collaborative international partnership that aims to halt mangrove loss, restore mangrove ecosystems, and increase mangrove cover by 20% by 2030.

COMPONENTS OF AN ECOSYSTEM

The components of ecosystem and environment are the same as following:

1) Abiotic Components

Abiotic components are the inorganic and non-living parts of the world. The abiotic part consists of soil, water, air and light, energy etc.it also involves like oxygen, nitrogen etc. physical processes including volcanoes, earthquakes, floods, forest fires, climates, and weather conditions. Abiotic factors are the most important determinants of where and how an organism exists in its environment. Although these factors interact with each other, one single factor can limit the range of an organism

(a) Energy

Energy from the sun is essential for maintenance of life. In the case of plants, the sun directly supplies the necessary energy. Since animals cannot use solar energy directly, they obtain it indirectly by eating plants or animals or both. Energy determines the distribution of organisms in the environment.

b) Rainfall and moisture

Water is essential for all living beings. Majority of biochemical reactions take place in an aqueous medium. Water helps to regulate body temperature. Further, water bodies form the habitat for many aquatic plants and animals.

c) Temperature and light

Temperature is a critical factor of the environment which greatly influences survival of organisms. Organisms can tolerate only a certain range of temperature and humidity.

d) Atmosphere

The earth's atmosphere is responsible for creating conditions suitable for the existence of a healthy biosphere on this planet.

e) Substratum

Land is covered by soil and a wide variety of microbes, protozoa, fungi and small animals (invertebrates) thrive in it. Roots of plants pierce through the soil to absorb water and nutrients. Organisms can be terrestrial or aquatic. Terrestrial animals live on land. Aquatic plants, animals and microbes live in fresh water as well as in the sea. Some microbes live even in hot water vents under the sea.

f) Materials:

(i) Organic compounds such as proteins, carbohydrates, lipids, humic substances are formed from inorganic compounds on decomposition.

(ii) Inorganic compounds such as carbon dioxide, water, Sulphur, nitrates, phosphates, and ions of various metals are essential for organisms to survive.

g**) Latitude and altitude**

Latitude has a strong influence on an area's temperature, resulting in changes of climates such as polar, tropical and temperate. These climates determine different natural biomes.

From sea level to highest peaks, wildlife is influenced by altitude. As the altitude increases, the air becomes colder and drier, affecting wildlife accordingly.

h) Topography

The physical structure of the earth is called its topography.

2) Biotic Components

The classification of biotic components is based on food and energy.

(a) Producers (Plants) or autotrophs: the ultimate source of energy for food production is sun. Only green plants having chlorophyll are capable of photosynthesis are known as the producers or autotrophs. They are also called self-nourishing, because they prepare themselves. This process is performed by microbes such as bacteria and algae (blue green algae). In terrestrial ecosystems, producers are basically herbaceous and woody plants, while in aquatic ecosystem producers are various species of microscopic algae and phytoplankton.

b) Consumers – Heterotrophs

Consumers naturally have no ability to produce their own food. They depend on organic food derived from plants, animals or both. Consumers can be divided into two major groups, namely micro and macro consumers.

Macro consumers

They get readymade food from plants or animals or both and are categorized based on their food sources.

• **Herbivores or primary consumers** nourish mainly on plants e.g. cows and rabbits.

Secondary consumers feed primary consumers e.g. wolves.

• **Tertiary consumers** which feed on secondary consumers are called tertiary consumers e.g. lions which can eat wolves, hawks which can eat rats.

• **Omnivores** are organisms which can eat both plants and animals e.g. man, monkey
Scavengers are organisms that feeds on carrion, dead plants materials or refuse. e.g. vulture and crows.

Parasites can feed on living organisms to suck their blood and harm them. They are consumers and causes diseases.

Micro consumers

saprotrophs (decomposers or osmographs)

They are bacteria and fungi which obtain energy and nutrients by decomposing dead organic substances (detritus) of plant and animal origin. Products of decomposition such as inorganic nutrients which are released in the ecosystem are reused by producers and thus recycled. Earthworms and certain soil organisms (such as nematodes, and arthropods) help in the decomposition of organic matter and are called derives.

GOODS AND SERVICES OF AN ECOSYSTEMS

• ecosystem can provide food, fuel and fiber.

• Provision of shelter for organisms as their habitat and timber for building materials.

• Purification of air and water and soil.

• Detoxification and decomposition of waste.

• Stabilization of the Earth's temperature and climate.

• Moderation of floods, droughts, temperature extremes and the forces of wind.

• Generation and renewal of soil fertility, including nutrient cycling.

• Pollination of plants, including many crops Control of pests and diseases, Maintenance of genetic resources as key inputs to crop varieties and livestock breeds and medicine.

- Cultural and aesthetic and recreational benefits.

FUNCTION OF AN ECOSYSTEM

The function of an ecosystem is a broad, vast and complete dynamic system. It can be studied under the following three heads.

• Energy flow

•Nutrient cycling (biogeochemical cycles)

• Ecological succession or ecosystem development

ENERGY FLOW IN ECOSYSTEM

Energy is the basic force responsible for all metabolic activities. The flow of energy through a trophic level from producer to top consumers is called energy flow which is unidirectional. This means that energy cannot be recycled. The study of Trophic level interaction in an ecosystem gives an idea about the energy flow through the ecosystem.

Trophic level interaction

Trophic level interaction deals with how the members of an ecosystem are connected based on nutritional needs. Energy flows through the trophic levels from producers to subsequent trophic levels. This energy always flows from lower (producer) to higher (herbivore, carnivore etc.) trophic level. It never flows in the reverse direction that is from carnivores to herbivores to producers. This means that energy is unidirectional. There is a loss of some energy in the form of unusable heat at each trophic level so that energy level decreases from the first trophic level upwards. As a result, there are usually four or five trophic levels and seldom more than six as beyond that very little energy is left to support any organism. Trophic levels are numbered according to the steps an organism is away from the source of food or energy that is the producer. The trophic level interaction involves three concepts namely:

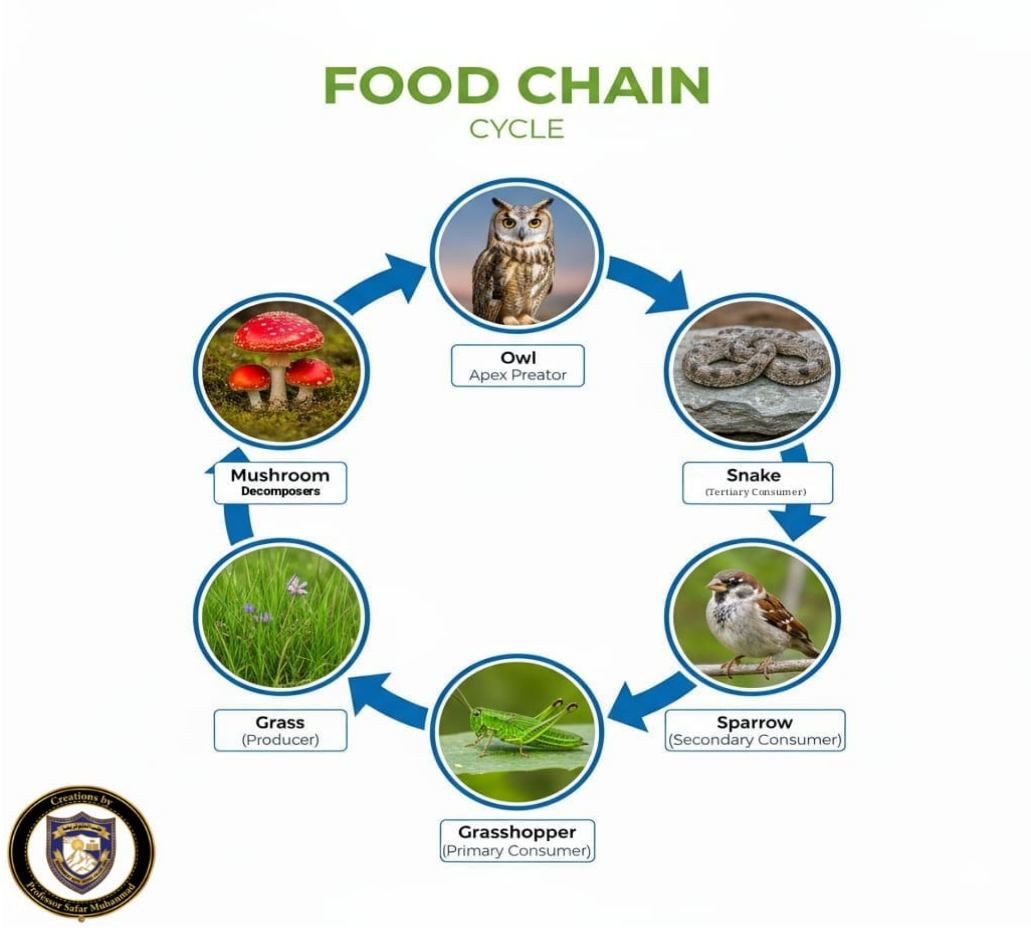
1. Food Chain

2. Food Web

3. Ecological Pyramids

FOOD CHAIN

Organisms in the ecosystem are related to each other through feeding mechanisms or trophic levels, i.e. one organism becomes food for the other. A sequence of organisms that feed on one another form a food chain. A food chain starts with producers and ends with top carnivores. The sequence of eaten and being eaten, produces and transfer food energy and it is known as food chain. The plant converts solar energy into chemical energy by photosynthesis. Small herbivores consume the plant matter and convert them into animal matter. These herbivores are eaten by large carnivores.



Two Types of Food chains

In nature, two main types of food chains have been distinguished:

(i) Grazing food chain

The consumers which start the food chain, utilizing the plant or plant part as their food, constitute the grazing food chain. This food chain begins with green plants at the base, and the primary consumer is herbivores. For example, in terrestrial ecosystem, grass is eaten by caterpillars, which is eaten by lizards and lizards are eaten by snakes. In the Aquatic ecosystem phytoplankton's (primary producers) is eaten by zoo planktons which is eaten by fishes and fish are eaten by pelicans.

(ii) Detritus food chain

It starts with dead organic matter of decaying animals and plant bodies consumed by the micro-organisms and then to detritus feeding organism called deprivers or decomposer and to other predators.

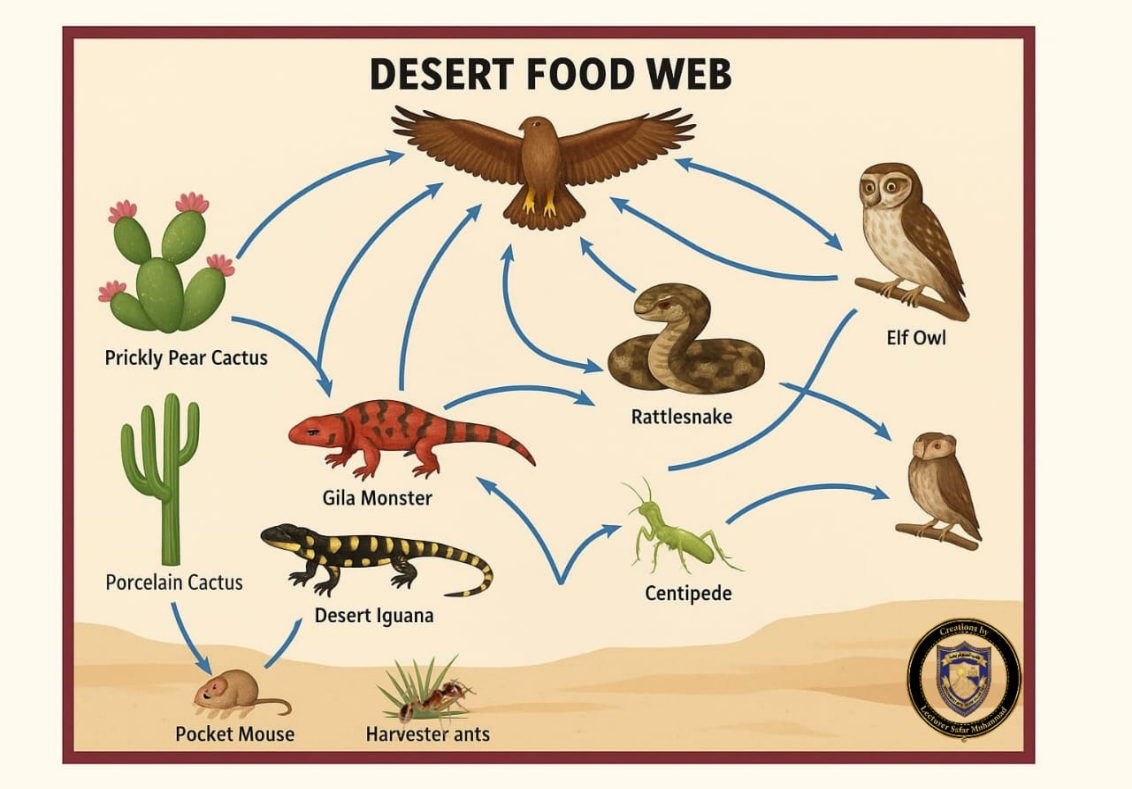
Litter ⟶ earthworms ⟶ Chicken ⟶ Hawk

The distinction between these two food chains is the source of energy for the first level consumers. In the grazing food chain, the primary source of energy is living plant biomass while in the detritus food chain the source of energy is dead organic matter or detritus. The two food chains are linked. The initial energy source for detritus food chain is the waste materials and dead organic matter from the grazing food chain as in following example.

FOOD WEB

A food chain represents only one part of the food or energy flow through an ecosystem and implies a simple, isolated relationship, which seldom occurs in the ecosystems. An ecosystem may consist of several interrelated food chains. More typically, the same food resource is part of more than one chain, especially when that resource is at the lower trophic levels. “A food web illustrates, all possible transfers of energy and nutrients among the organisms in an ecosystem, whereas a food chain traces only one pathway of the food”.

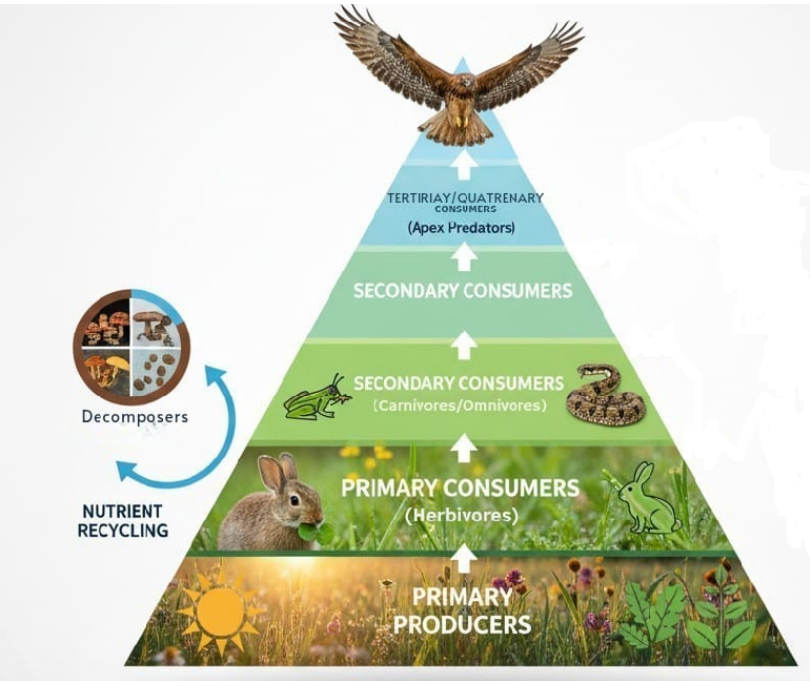
If any of the intermediate food chain is removed, the succeeding links of the chain will be affected largely. The food web provides more than one alternative for food to most of the organisms in an ecosystem and therefore increases their chance of survival. For example, grasses may serve food for rabbit, at the Same time it may be food source for grasshopper, goat and cow. Similarly an herbivore may be food source for many carnivorous species.



Also, food availability and preferences of food of the organisms may shift seasonally e.g. we eat watermelon in summer and peaches in the winter. Thus, there are interconnected networks of feeding relationships that take the form of food webs.

ECOLOGICAL PYRAMIDS

The steps of trophic levels expressed in a diagrammatic way are referred as ecological pyramids. The food producer forms the base of the pyramid, and the top carnivore forms the tip. Other consumer trophic levels are in between. The pyramid consists of several horizontal bars depicting specific trophic levels which are arranged sequentially from primary producer level through herbivore, carnivore onwards. The length of each bar represents the total number of individuals at each trophic level in an ecosystem. The number, biomass and energy of organisms gradually decrease with each step from the producer level to the consumer level and the diagrammatic representation assumes a pyramid shape as shown in following image.



The ecological pyramids are of three categories.

1. Pyramid of numbers,

2. Pyramid of biomass, and

3. Pyramid of energy or productivity.

Pyramid of Numbers

This deals with the relationship between the numbers of primary producers and consumers of different levels. It is a graphic representation of the total number of individuals of different species, belonging to each trophic level in an ecosystem. Depending upon the size and biomass, the pyramid of numbers may not always be upright, and may even be completely inverted.

(a) Pyramid of numbers – upright

• In this pyramid, the number of individuals is decreased from lower level to higher trophic level.

• This type of pyramid can be seen in grassland ecosystem.

•The grasses occupy the lowest trophic level (base) because of their abundance.

• The next higher trophic level is primary consumer - herbivore (example – grasshopper).

• The individual number of grasshoppers are less than that of grass. The next energy level is primary carnivore (example – frogs and birds).

• The number of birds are less than grasshoppers, because they feed on grasshoppers. The next higher trophic level is secondary carnivore (example – snakes). They feed on birds.

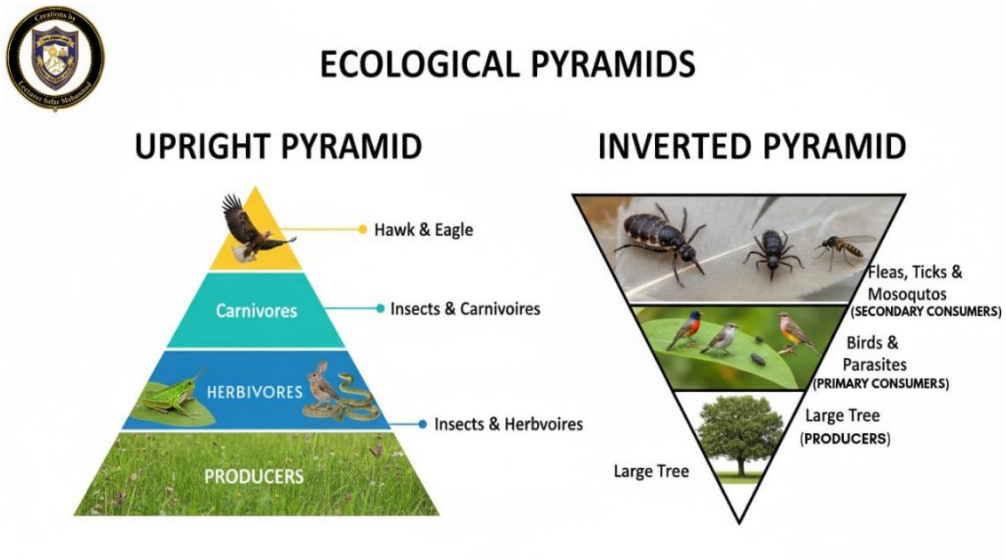
• The next higher trophic level is the top carnivore. (Ex. Hawk).

• With each higher trophic level, the number of individuals decreases.

(b)Pyramid of numbers – inverted

In this pyramid, the number of individuals will increase from lower level to higher trophic level. A count in a forest would have a small number of large producers, for example few numbers of big trees. This is because the tree (primary producer) being few and would represent the base of the pyramid and the dependent herbivores (Example - bees) in the next higher trophic level and it is followed by parasites in the next trophic level. Hyper parasites being at a higher trophic level represents higher in number and the resulting pyramid is in inverted shape.

A pyramid of number does not consider the fact that the size of organisms being counted at each trophic level can vary. It is very difficult to count all the organisms in a pyramid of numbers, so the pyramid of numbers does not completely define the trophic structure for an ecosystem.

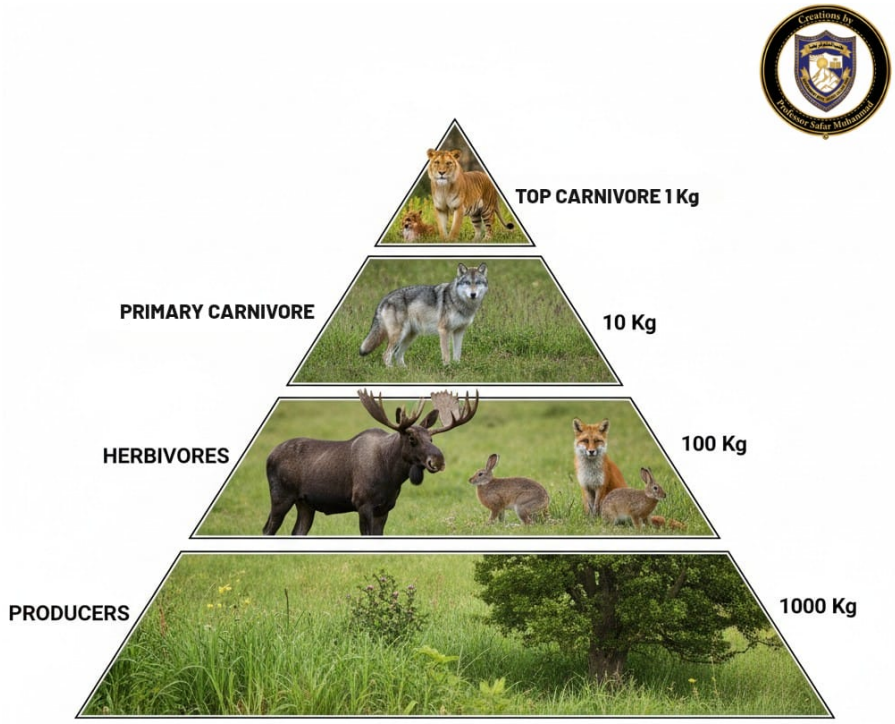


Pyramid of Biomass

To overcome the shortcomings of pyramid of numbers, the pyramid of biomass is used. In this approach individuals at each trophic level are weighed instead of being counted. This gives us a pyramid of biomass, i.e., the total dry weight of all organisms at each trophic level at a particular time. Pyramid of biomass is usually determined by collecting all organisms occupying each trophic level separately and measuring their dry weight. This overcomes the size difference problem because all kinds of organisms at a trophic level are weighed. Biomass is measured in g/m^2.

(a) Upward pyramid

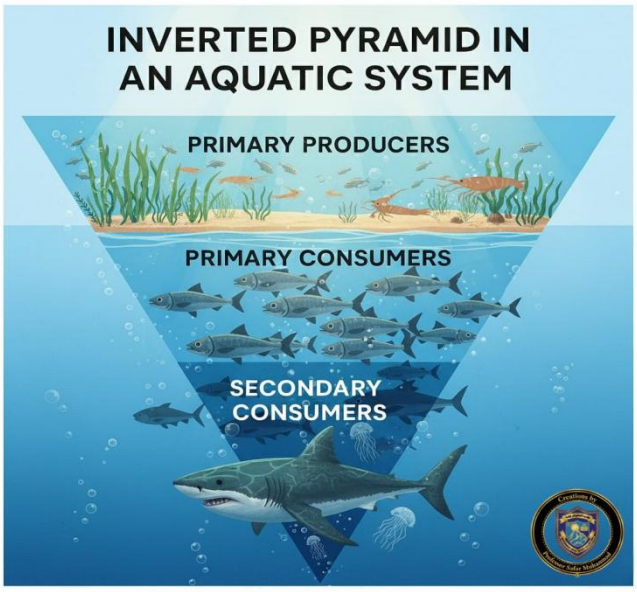
For most ecosystems on land, the pyramid of biomass has a large base of primary producers with a smaller trophic level perched on top. The biomass of producers (autotrophs) is at the maximum. The biomass of next trophic level i.e primary consumers is less than the producers. The biomass of next higher trophic level i.e secondary consumers is less than the primary consumers. The top, high trophic level has very less amount of biomass.



Upright Pyramid of Biomass in a Terrestical Ecoystem

b) Inverted pyramid

In Contrast of terrestrial ecosystems, in many aquatic ecosystems, the pyramid of biomass may assume an inverted form. This is because the producers are tiny phytoplankton that grow and reproduce rapidly. Here, the pyramid of biomass has a small base, with the consumer biomass at any instant exceeding the producer biomass and the pyramid assumes inverted shape.



Pyramid of Energy

To compare the functional roles of the trophic levels in an ecosystem, an energy pyramid is most suitable. An energy pyramid reflects the laws of thermodynamics, with conversion of solar energy to chemical energy and heat energy at each trophic level and with loss of energy being depicted at each transfer to another trophic level. Hence the pyramid is always upward, with a large energy base at the bottom. Let us explain this with an example. Suppose an ecosystem receives 100 % of light energy each day. Most of the energy is not absorbed; some is reflected to space; of the energy absorbed, only a small portion is utilized by green plants, out of which the plant uses up some for respiration. Therefore, most of energy is dissipated and only a small fraction is stored as energy rich materials.

Now suppose an animal, say a deer, receives the grass containing 10% of food energy. The grasshopper uses some of it for its own metabolism and transfers only 1% food energy. A frog that eats the grasshopper gets an even smaller amount of energy and transfers an amount of energy less than 0.1% to the next trophic level. Thus, usable energy decreases from sunlight to producer to herbivore to carnivore. Therefore, the energy pyramid will always be upright. Energy pyramid concept helps to explain the phenomenon of biological magnification, that is the tendency for toxic substances to increase concentration progressively at higher levels of the food chain.

BIOTIC INTERACTIONS (based on nutrition)

Organisms living in the biosphere are interlinked for many needs. The most basic need is food and shelter. The interaction between the organisms is fundamental for its survival and functioning of ecosystem.

Biotic interactions			
S.NO.	TYPE	SPECIES 1	SPECIES 2
1	Mutualism	(+)	(+)
2	Commensalism	(+)	(0)
3	Mentalism	(-)	(0)
4	Competition	(-)	(-)
5	Predation	(+)	(-)
6	Parasitism	(+)	(-)
(+) Benefited (–) Harmed (0) Neither benefited nor harmed.			

Mutualism

Both species benefit. Example: in pollination mutualisms, the pollinator gets food (pollen, nectar), and the plant has its pollen transferred to other flowers for cross-fertilization (reproduction).

Commensalism:

One species benefit, the other is unaffected. Example: cow dung provides food and shelter to dung beetles. The beetles have no effect on the cows.

Competition

Both species are harmed by interaction. Example: if two species eat the same food, and there isn't enough for both, both may have access to less food than they would if alone. They both suffer a shortage of food.

Predation and parasitism

One species benefit, the other is harmed. Example: predation—one fish kills and eats parasitism: tick gains benefit by sucking blood; host is harmed by losing blood.

Mentalism

One species is harmed, the other is unaffected. Example: A large tree shades a small plant, retarding the growth of the small plant. The small plant has no effect on the large tree.

Neutralism

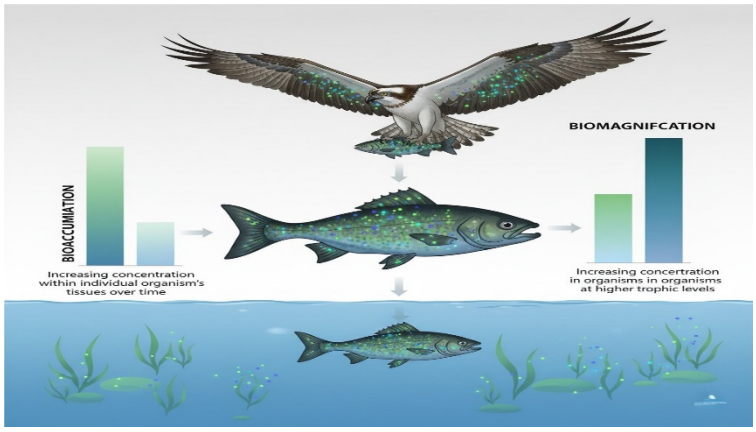
There is no net benefit or harm to either species. Perhaps in some interspecific interactions, the costs and benefits experienced by each partner are the same so that they sum to zero. It is not clear how often this happens in nature. Neutralism is also sometimes described as the relationship between two species inhabiting the same space and using the same resources, but that have no effect on each other. In this case, one could argue that they aren't interacting at all.

Pollutants accumulation in the trophic level

Pollutants, especially non-degradable ones move through the various trophic levels in an ecosystem. Non degradable pollutants mean materials which cannot be metabolized by living organisms. Example: chlorinated hydrocarbons. Scientists are concerned about these phenomena because, together they enable even small concentrations of chemicals in the environment to find their way into organisms is enough dosages to cause problems. Movement of these pollutants involves two main processes are:

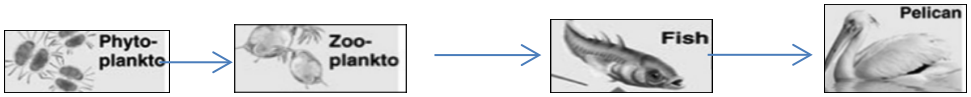
Bioaccumulation

It refers that how pollutants enter a food chain. In bioaccumulation there is an increase in concentration of pollutants from the environment to the first organism in a food chain.


BIOMAGNIFCATION
BIOACCUMIATION
Increasing concentration within individual organism's tissues over time
Increasing concertration in organisms in organisms at higher trophic levels

Biomagnification

Tendency of pollutants to concentrate as they move from one trophic level to the next. Thus, in biomagnification there is an increase in concentration of a pollutant from one link in a food chain to another. For biomagnification to occur, the pollutant must be long-lived, mobile, soluble in fats, biologically active. If a pollutant is short-lived, it will break down before it can become dangerous. If it is not mobile, it will stay in one place and is unlikely to be taken up by organisms. If the pollutant is soluble in water, it will be excreted by the organism. Pollutants that dissolve in fats, however, may be retained for a long time. It is traditional to measure the amount of pollutants in fatty tissues of organisms such as fish. In mammals, we often test the milk produced by females, since the milk has a lot of fat in it are often more susceptible to damage from toxins (poisons). If a pollutant is not active biologically, it may bio magnify, but we really don't worry about it much, since it probably won't cause any problem. One of the best examples of bio magnification is the DDT in brown pelicans.



Biomagnification of DDT in brown pelican.

The nutrient cycle is a concept that describes how nutrients move from the physical environment to the living organisms and subsequently recycle back to the physical environment. This movement of nutrients from the environment into plants and animals and again back to the environment is essential for life and it is the vital function of the ecology of any region. In any particular environment, to maintain its organism in a sustained manner, the nutrient cycle must be kept balanced and stable. Nutrient cycling is typically studied in terms of specific nutrients, with each nutrient in an environment having its own particular pattern of cycling. Among the most important nutrient cycles are the carbon nutrient cycle and the nitrogen nutrient cycle. Both of these cycles make up an essential part of the overall soil nutrient cycle. There
Are many other nutrient cycles that are important in ecology, including a large number of trace mineral nutrient cycles?
Based on the nature of the reservoir, there are two
types of cycles namely Gaseous and sedimentary cycle
Gaseous Cycle – where the reservoir is the atmosphere
or the hydrosphere, and
Sedimentary Cycle – where the reservoir is the earth's
crust.

WATER CYCLE (HYDROLOGIC)

The water cycle, also known as the hydrologic cycle, is the continuous process by which water is circulated between the Earth's oceans, atmosphere, and land.

Water from the oceans, lakes, rivers, and the ground surface evaporates into the atmosphere, forming water vapor. Plants also absorb water from the soil and release it into the atmosphere as water vapor through a process called transpiration.

Water vapor in the atmosphere condenses into clouds, fog, or dew. Then Water droplets in clouds grow and eventually fall to the ground as precipitation (rain, snow, sleet, or hail). Precipitation that falls on land flows over the surface as runoff, eventually returning to bodies of water. Some precipitation seeps into the soil and becomes groundwater. Groundwater moves downward through the soil layers and becomes part of the groundwater storage.

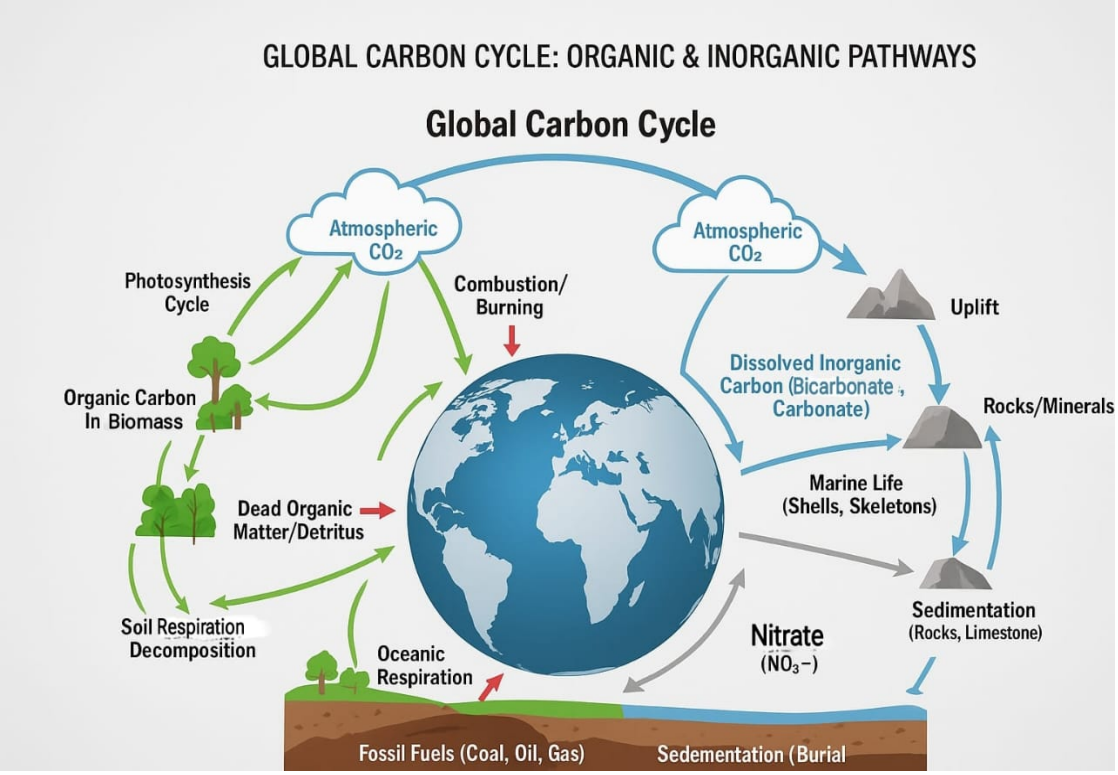
CARBON CYCLE

Short term

Carbon is present in the atmosphere, mainly in the form of carbon dioxide (CO_2). Carbon cycles involve a continuous exchange of carbon between the atmosphere and organisms. Carbon from the atmosphere moves to green plants by the process of photosynthesis, and then to animals. By process of respiration and decomposition of dead organic matter it returns to atmosphere. It is usually a short-term cycle.

Long term carbon cycle

Some carbon also enters a long-term cycle. It accumulates as undecomposed organic matter in the peaty layers of marshy soil or as insoluble carbonates in the bottom sediments of aquatic systems which take a long time to be released. In deep oceans such carbon can remain buried for millions of years till geological movement may lift these rocks above sea level. These rocks may be exposed to erosion, releasing their carbon dioxide, carbonates and bicarbonates into streams and rivers. Fossil fuels such as coals, oil and natural gas etc. are organic compounds that were buried before they could be decomposed and were subsequently transformed by time and geological processes into fossil fuels. When they are burned the carbon stored in them is released back into the atmosphere as carbon-dioxide.



NITROGEN CYCLE

Nitrogen is an essential constituent of protein and is a basic building block of all living tissue. It constitutes nearly 16% by the weight of all the proteins. There is an inexhaustible supply of nitrogen in the atmosphere, but the elemental form cannot be used directly by most of the living organisms. Nitrogen needs to be 'fixed', that is, converted to ammonia, nitrites or nitrates, before it can be taken up by plants.

Nitrogen fixation on earth is accomplished in three different ways:

(i) By microorganisms (bacteria and blue-green algae)

(ii) By man using industrial processes (fertilizer factories)

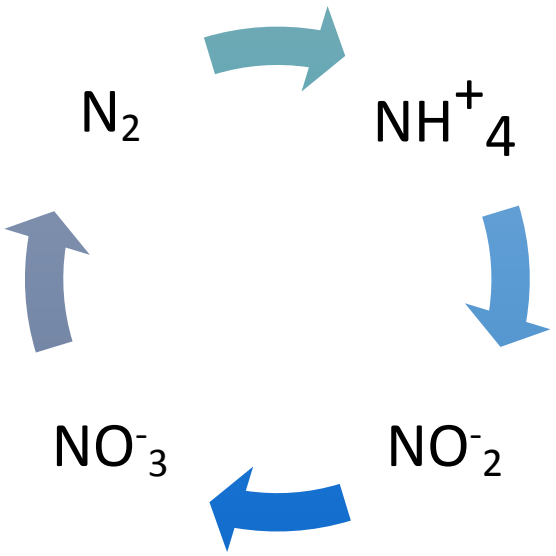
(iii) To a limited extent by atmospheric phenomenon such as thunder and lightning.

The most important is the one which is proceeding by microorganisms. This cyclic flow depends not only on decomposers but also on various types of enzymes. Decomposers use several enzymes in the breakdown of protein in dead organisms. These enzymes are produced by many soil organisms. Following are the most important enzymes which are produced by microorganisms.

proteinase: break protein molecules into smaller molecules by actinomycetes and many fungi.

Peptidases: break peptide bonds to release amino acids.

Deaminases: remove amino group from amino acids and release ammonia (NH_3), eventually free nitrogen gas fixed its way back into the atmosphere.



1) **Nitrogen fixation**

Nitrogen fixation is the reduction of atmospheric nitrogen into ammonium ions and ammonia gas. Certain microorganisms are capable of fixing atmospheric nitrogen. Most capable is bacteria called Nitrogen fixing bacteria. These bacteria must have a functional nitrogen-fixing enzyme called nitrogenase, which is a reducing agent that supplies hydrogen. These are symbiotic bacteria which thrive in the nodules on the roots of leguminous plants like beams, peas, clover etc.

These include free living nitrifying bacteria (e.g. aerobic Azotobacter and anaerobic Clostridium) and symbiotic nitrifying bacteria living in association with leguminous plants (e.g. Rhizobium) and symbiotic bacteria living in non-leguminous root nodules such as different types of blue green algae (e.g. Anabaena, Spirulina).

Rhizobium bacteria and root nodules

Rhizobium is the primary symbiotic fixer. It lives in nodules, growth extending from roots of certain plants usually legumes. In this relationship, the plant benefits by receiving

nitrogen in a usable form and bacteria benefits by receiving nutrients for growth and protection. The enzyme nitrogenase catalyzes the following reaction.

$N_2 + 3H_2 \xrightarrow{\text{rhizobium \& nitrogenase}} 2NH_3$

2) Nitrification

Ammonium ions can be directly taken up as a source of nitrogen by some plants and are oxidized to nitrites or nitrates by two groups of specialized bacteria: Nitrosomonas Bacteria promote transformation of ammonia into nitrite. Nitrite is then further transformed into nitrate by the bacteria Nitrobacter. The two-step reaction is as follows.

$NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^- + H_2O + 2H^+ + \text{energy}$

Step 2

$NO_2 + ½\ O_2 \xrightarrow{\text{Nitrobacter}} NO_3^- + \text{energy}$

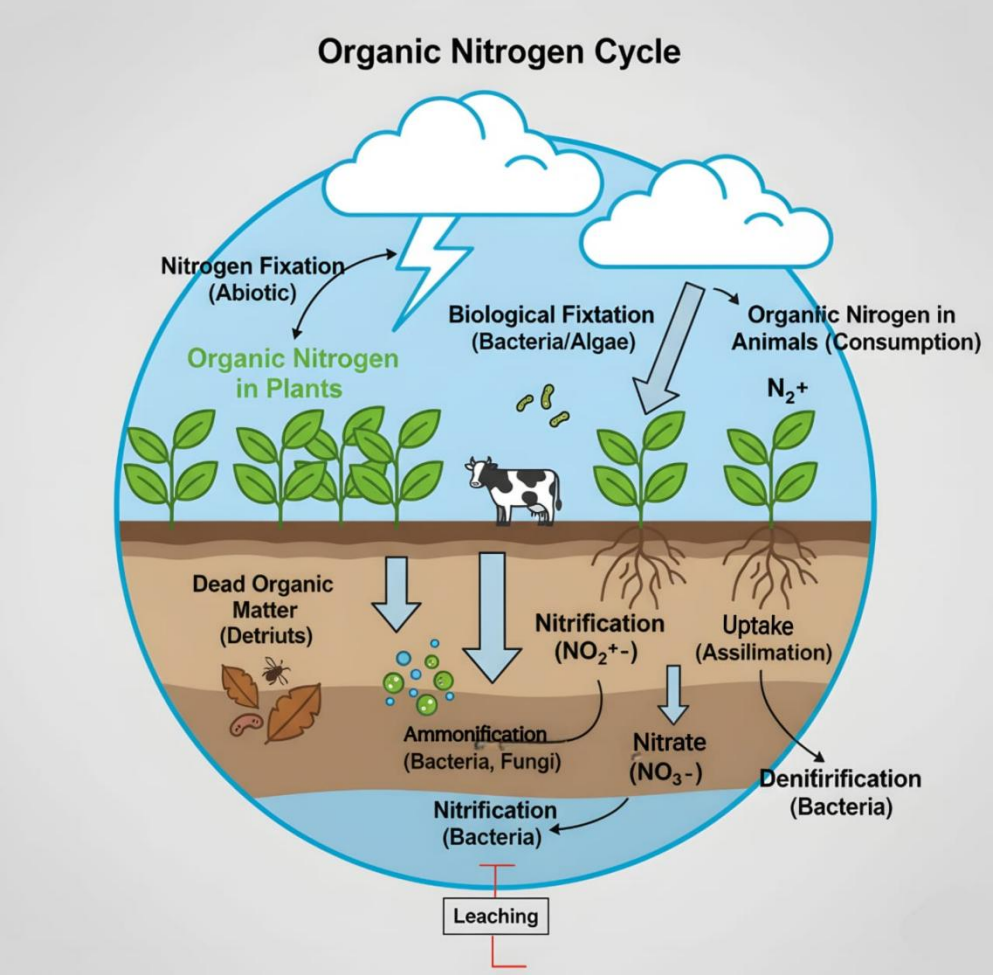
This form of nitrogen is the most usable in plants metabolism. The nitrates synthesized by bacteria in the soil are taken up by plants and converted into amino acids, which are the building blocks of proteins. These then go through higher trophic levels of the ecosystem. During excretion and upon the death of all organisms, nitrogen is returned to the soil in the form of ammonia. Certain quantity of soil nitrates, being highly soluble in water is lost from topsoil by being transported away by surface run-off or ground water.

3) Denitrification

Denitrification is the process by which nitrogenous compounds formed by ammonification and nitrification are converted into free nitrogen. In the soil as well as oceans there are special denitrifying bacteria (e.g. Pseudomonas), which convert the nitrates/nitrites to elemental nitrogen.

$HNO_3^- \rightarrow NO_2^- \rightarrow N_2O \rightarrow N_2$

This nitrogen escapes into the atmosphere, thus completing the cycle. The periodic thunderstorms convert the gaseous nitrogen in the atmosphere to ammonia and nitrates which eventually reach the earth's surface through precipitation and then into the soil to be utilized by plants.

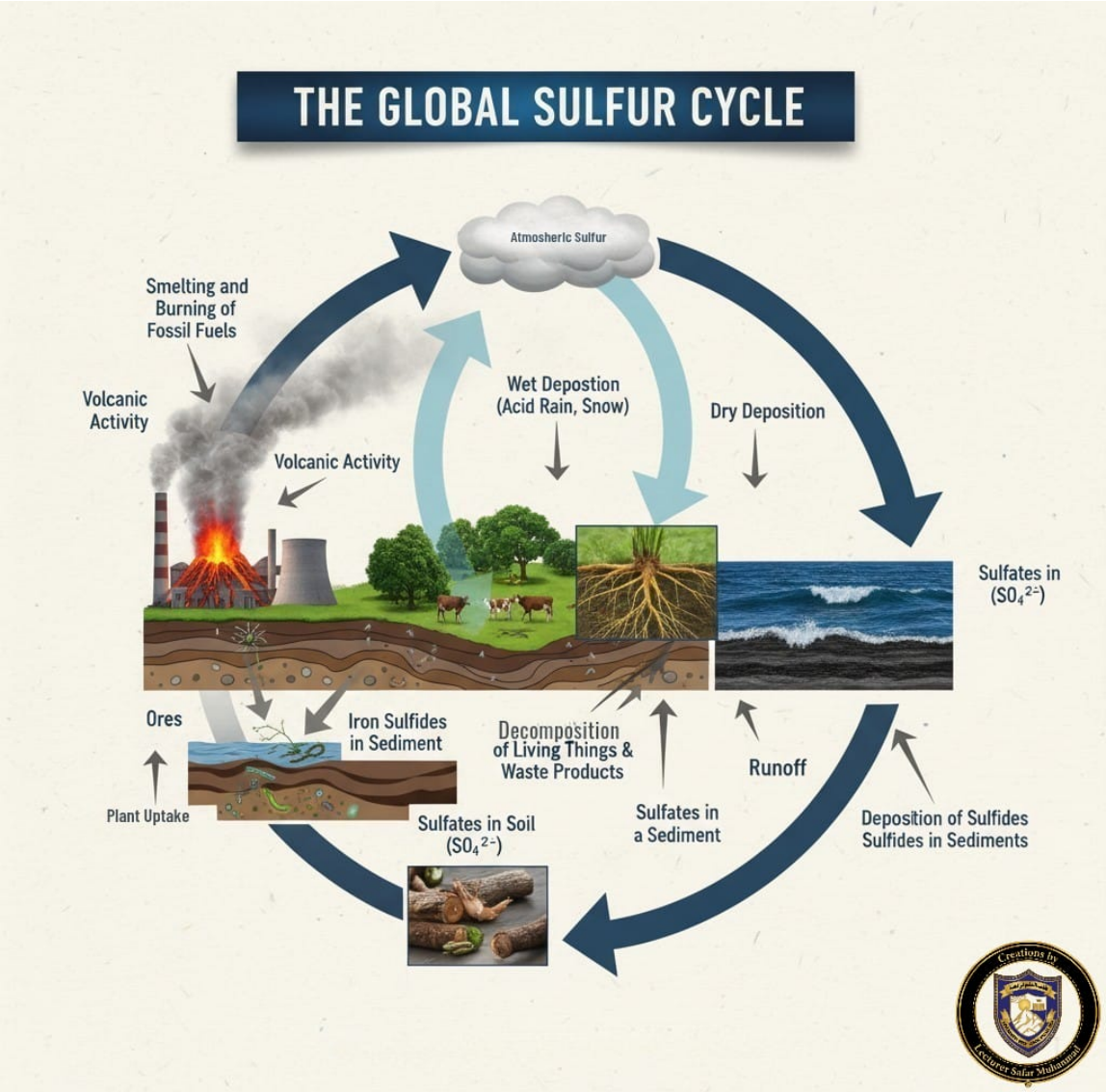


SULPHUR CYCLE

The Sulphur reservoir is in the soil and sediments where it is locked in organic (coal, oil and peat) and inorganic deposits (pyrite and Sulphur rocks) in the form of sulphates, sulfides and organic Sulphur. It is released by weathering of rocks, erosional runoff and deposition of organic matter and is carried to terrestrial and aquatic ecosystems in salt solution.

The Sulphur cycle is mostly sedimentary except for two of its compounds i.e hydrogen sulfide (H_2S) and Sulphur dioxide (SO_2) add a gaseous component to its' normal sedimentary cycle. Sulphur enters the atmosphere from several sources like volcanic eruptions, combustion of fossil fuels, from surface of ocean and from gases released by decomposition. Atmospheric hydrogen sulfide from volcanic eruptions and from iron sulfide (FeS) (in sedimentary rocks, ores and sediments reduced to H_2S) is also gets oxidized into Sulphur dioxide. Atmospheric Sulphur dioxide is carried back to the earth after being dissolved in rainwater as weak sulfuric acid in the form of wet deposition. Whatever the source, Sulphur in the form of sulphates is take up by plants and incorporated through a series of metabolic processes into Sulphur bearing amino acids, which is incorporated in the proteins of autotrophs tissues. It then passes through the grazing food chain. Sulphur bond in living organisms is carried back to the soil, to the bottom of ponds and lakes and seas through excretion and decompositibioon of dead organic matter. DMS (Dimethyl sulfide; CH_3SCH_3) is also a naturally occurring compound produced in ocean

waters through biological bacterial processes and then escapes to atmosphere from water surface.



SEDIMENTARY CYCLE

Phosphorus, calcium and magnesium circulate by means of the sedimentary cycle. The element involved in the sedimentary cycle normally does not cycle through the atmosphere but follows a basic pattern of flow through erosion, sedimentation, mountain building, volcanic activity and biological transport through the excreta of marine birds.

PHOSPHOROUS CYCLE

Phosphorous is required in small quantities both by plants and animals. Phosphorous plays a central role in aquatic ecosystems and water quality. Unlike carbon and nitrogen, which come primarily from the atmosphere, phosphorous occurs in large amounts as a mineral in phosphate (PO_4^{-3}) rocks and enter the cycle from erosion and mining.

The green plants take up the phosphorous from soil present as inorganic form. Phosphorous enter in the food chain, on the decay after the death of plants and animals, phosphorous again available for plant uptake. This is called the biological pathway of this element.

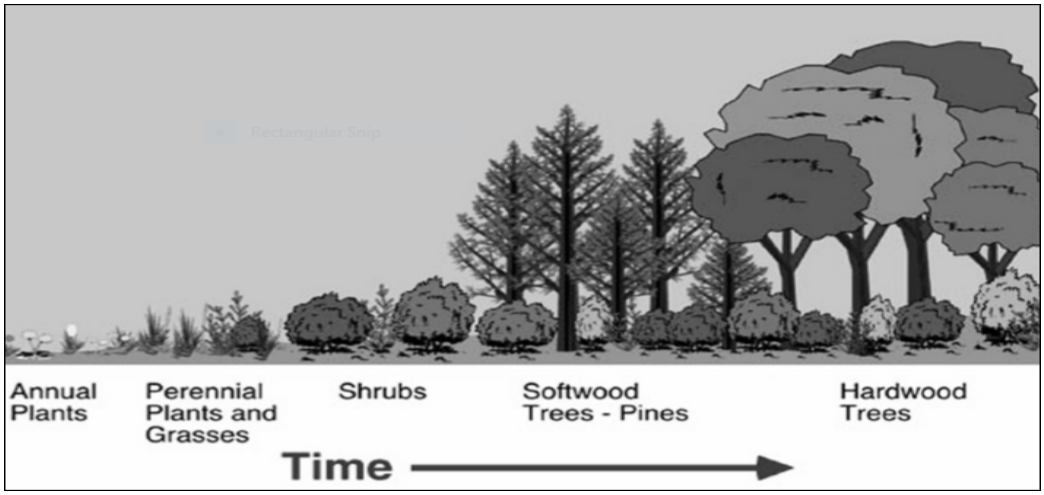
The other phase is a long phase called sedimentary phase. The main storage of phosphorous is in earth's crust. By the processes of weathering and erosion, phosphate enter rivers and streams that transport them to the ocean. In the ocean, once the phosphorous accumulates

On continental shelves in the form of insoluble deposits. After millions of years, the crystal plates rise from sea floor and expose the phosphates to land. After more time, weathering will release them from rock, and the cyclic geochemical phase begins again.

ECOLOGICAL SUCCESSION AND COMMUNITY DYNAMICS

Succession is a universal process of directional change in vegetation, on an ecological time scale. Succession occurs when a series of communities replace one another due to large scale destruction either natural or manmade. This process continues - one community replacing another community, until a stable, mature community develops. Succession is a progressive series of changes which leads to the establishment of a relatively stable climax community.

The first plant to colonize an area is called the pioneer community. The final stage of succession is called the Climax Community. The stages leading to the climax community are called successional stages or series. Succession is characterized by the following: increased productivity, the shift of nutrients from' the reservoirs, increased diversity of organisms with increased niche development, and a gradual increase in the complexity of food webs.



Ecological succession

PRIMARY SUCCESSION

In primary succession on a terrestrial site the new site is first colonized by a few hardy pioneer species that are often microbes, lichens and mosses. The pioneers over a few generations alter the habitat conditions by their growth and development. These new conditions may be conducive to the establishment of additional organisms that may subsequently arrive at the site. The pioneers through their death any decay leave patches of organic matter in which small animals can live. The organic matter produced by these pioneer species produces organic acids during decomposition that dissolve and percolate to the substratum releasing nutrients there. Organic debris accumulates in pockets and crevices, providing soil in which seeds can become lodged and grow. As the community of organisms continues to develop, it becomes more diverse and competition increases, but at the same time new niche opportunities develop. The pioneer species disappear as the habitat conditions change and the invasion of new species progresses, leading to the replacement of the preceding community.

SECONDARY SUCCESSION

Secondary succession occurs when plants recognize an area in which the climax community has been disturbed. Secondary succession is the sequential development of biotic Communities after the complete or partial destruction of the existing community. A mature or intermediate community may be destroyed by natural events such as floods, droughts, fires, or storms or by human interventions such as deforestation, agriculture, overgrazing, etc. This abandoned farmland is first invaded by hardy species of grasses that can survive in bare, sunbaked soil. These grasses may be soon joined by tall grasses and herbaceous plants. These dominated the ecosystem for some years along with mice, rabbits, insects and seed-eating birds. Eventually, some trees come up in this area, seeds of which may be brought by wind or animals. And over the years, a forest community has developed. Thus, an abandoned farmland over a period becomes dominated by trees and is transformed into a forest. The differences between primary and secondary succession are that the

primary succession organize over a barren land after receiving necessary life conditions while the secondary succession starts on a well-developed soil already formed at the site. Thus, secondary succession is relatively faster as compared to primary succession which may often require hundreds of years.

Autogenic and Allogenic Succession

When succession is brought about by living inhabitants of that community itself, in other words, the driven forces for change are organism themselves then the process is called autogenic succession, while change brought about by outside forces such as earth quicks, floods, disaster's etc. is known as allogenic succession.

Autotrophic and Heterotrophic succession

Succession, in which, initially the green plants are much greater in quantity is known as autotrophic succession; and the ones in which the heterotrophs are greater in quantity is known as heterotrophic succession. Succession would occur faster in areas existing in the middle of the large continent. This is because, here all seeds of plants belonging to the different series would reach much faster, establish and ultimately result in climax community.

CHAPTER 3 THE ATMOSPHERIC

STRUCTURE & COMPOSITION OF ATMOSPHERE

Without our atmosphere, there would be no life on earth. In the natural atmosphere (means have no pollution), two gases make up predominately part of the earth's atmosphere: nitrogen (78%), and oxygen (21%). Argon (0.9%), carbon dioxide (0.03%) and various trace gases make up the remainder.

Scientists divided the atmosphere into different major layers according to temperature, pressure and altitude: troposphere, stratosphere, mesosphere, and thermosphere. The temperature drops as we go up through the troposphere called **adiabatic lapse rate**, but it rises as we move through the next layer, the stratosphere. So, there is alternative changes (up, down) in temperature between atmospheric layers. The farther away from earth, the thinner the atmosphere gets.

ATMOSPHERIC TEMPERATURE AND PRESSURE PROFILE

TROPOSPHERE

This is the layer of the atmosphere closest to the Earth's surface, extending up to about 10-15 km above the Earth's surface. It contains 75-80% of the atmosphere's mass. The troposphere is wider at the equator than at the poles. Temperature and pressure drop as we go higher up the troposphere. There is gradual fall of 5 degrees in temperature per 10 kilometers in the troposphere adiabatically called **lapse rate**. Most weather phenomena occur in this layer.

Our sphere works on **joule Thomson affect,** which says “at ordinary temperatures and pressures, all real gases cool upon expansion”.

The Tropopause:

At the very top of the troposphere is the Tropopause where the temperature reaches a (stable) minimum, mostly (-56℃). Some scientists call the Tropopause a "thermal layer" or "cold trap" because this is a point where rising water vapor cannot go higher because it changes into ice and is trapped. If there is no cold trap, Earth would lose all its water.

Most of what we call weather occurs in the troposphere. The uneven heating of the regions of the troposphere by the Sun causes convection currents and winds. Warm air from Earth's surface rises and cold air above it rushes in to replace it. When warm air reaches the Tropopause, it cannot go higher as the air above it (in the stratosphere) is warmer and lighter preventing much air convection beyond the Tropopause. The Tropopause acts like an invisible barrier and is the reason why most clouds form and weather phenomena occur within the troposphere.

2) STRATOSPHERE

This layer lies directly above the troposphere and is about 35 km deep. It extends from about 15 to 50 km above the Earth's surface. It contains roughly 10-20% of the

atmosphere's mass. The stratosphere is warmer at the top (-2°C) than the bottom. The lower portion has a nearly constant temperature with height but in the upper portion the temperature increases with altitude because of absorption of sunlight by ozone (this means that exothermic reactions occur because of high frequency ultraviolet rays). This temperature increase with altitude is the opposite of the situation in the troposphere.

THE OZONE LAYER FORMATION

Stratosphere contains a thin layer (3 to5mm) of ozone molecules (with three oxygen atoms).At an altitude of about 30km, the concentration of ozone in stratosphere is about 10ppm, which forms a protective layer shielding life on Earth from the Sun's harmful ultraviolet radiation (220-330nm) and thereby protect the life on earth from severe radiation damage, such as mutation, skin cancer and soft tissues and damage of eye. Only small fractions of *UV* rays (called *UVA* type) reach the lower atmosphere and the earth's surface. This ozone layer is getting thinner over Europe, Asia, North American and especially higher latitudes like Antarctica. "Holes" are appearing in the ozone layer. The holes are sparse ozone sites. The concentration of ozone is measuring in Dobson scale.

The Chapman Cycle (ozone formation)

The stratosphere is in a constant cycle with oxygen molecules and their interaction with ultraviolet rays. This process is considered a cycle because of its constant conversion between different molecules of oxygen. The ozone layer is created when ultraviolet rays react with oxygen molecules (O2) to create ozone (O3) and atomic oxygen (O). This process is called the **Chapman cycle**.

An oxygen molecule is photolyzed by solar radiation in photochemical reactions creating two oxygen radicals:

$$O_2 + h\nu (242nm) \rightarrow O^{\circ} + O^{\circ}$$

Oxygen radicals then react with molecular oxygen to produce ozone:

$$O^{\circ} + O_2 + M^* \text{ (third body is less reactive than } O^{\circ}) \rightarrow O_3 + M$$

Ozone then reacts with an additional oxygen radical to form molecular oxygen:

$$O3 + O. \rightarrow 2O2$$

Ozone can also be recycled into molecular oxygen by reacting with a photon:

$$O3 + h\nu \rightarrow O2 + O.$$

It is important to keep in mind that the ozone layer is constantly being created and destroyed by the Chapman cycle and that these reactions are natural processes, which have been taking place for millions of years. Because of this, the thickness of the ozone layer at any particular time can vary greatly. It is also important to know that O_2 is constantly being introduced into the atmosphere through photosynthesis, so the ozone layer has the capability of regenerating itself.

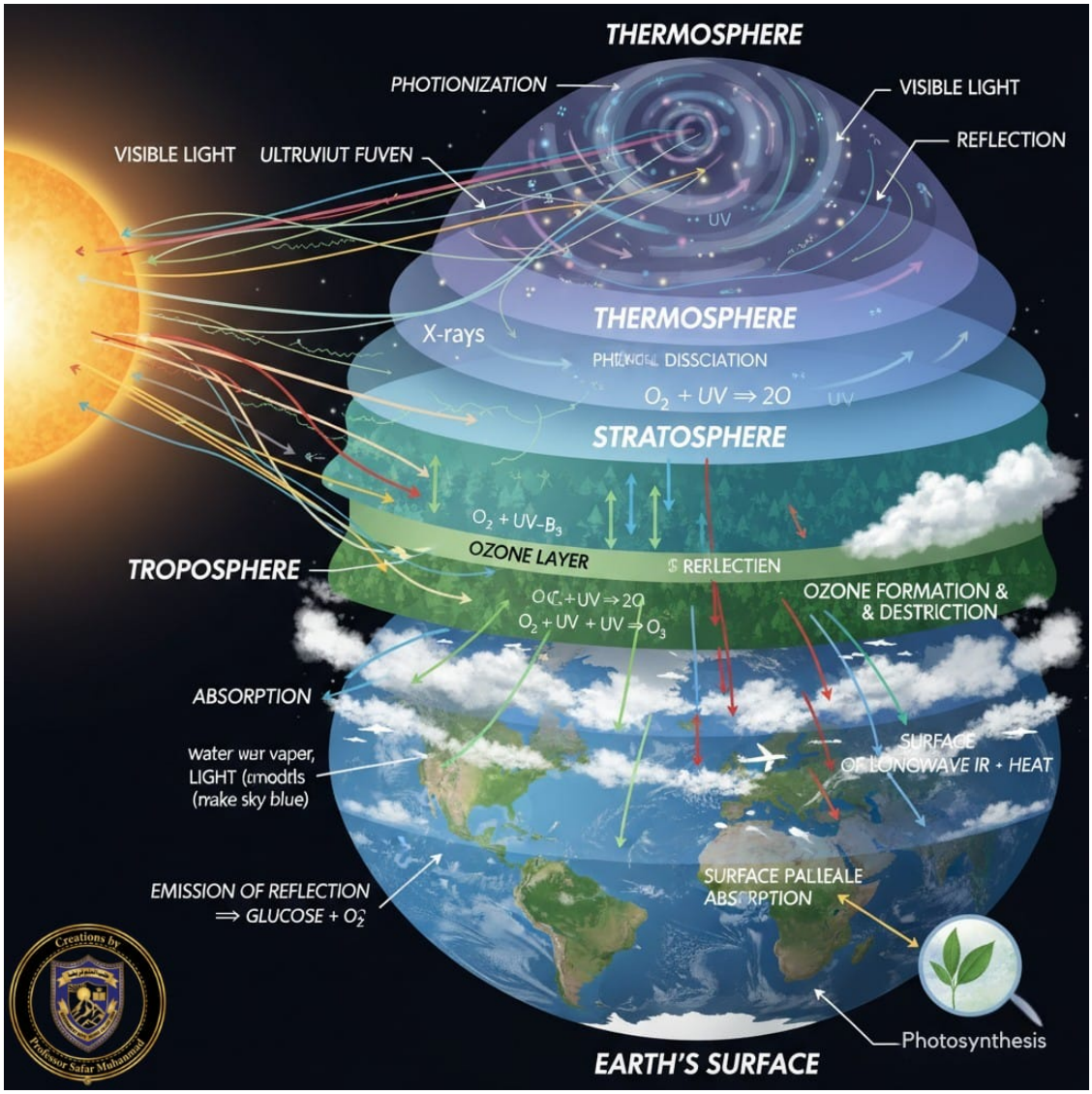
3) MESOSPHERE

Directly above the stratosphere, extending from 50 to 80 km above the Earth's surface. The mesosphere is a cold layer where the temperature generally decreases (-92°) with increasing altitude. Here in the mesosphere, the atmosphere is very rarefied, nevertheless thick enough

to slow down meteors hurtling into the atmosphere, where they burn up, leaving fiery trails in the night sky.

4) THERMOSPHERE

The thermosphere extends from 80 km above the Earth's surface to outer space. The temperature is hot and may be as high as thousands of degrees as the few molecules that are present in the thermosphere receive extraordinarily large amount of energy from the Sun. However, the thermosphere would feel very cold to us because the probability that these few molecules that have very low pressure will hit our skin and transfer enough energy to cause appreciable heat is extremely low. The thermosphere corresponds to the **heterosphere**, a zone where there is no uniform distribution of gases. In other words, the gases are not well-mixed; instead, they are stratified and is layered in accordance to their molecular masses. In contrast, the gases in the chemosphere (consisting of the troposphere, stratosphere and mesosphere) are uniformly distributed.



5) EXOSPHERE

the exosphere is the outermost layer of the planets earth, extending 500-1000 km altitude.it is the region where the atmosphere interacts with the solar wind, a stream of charged particles emitted by the sun. This layer is extremely thin, with atmospheric pressure decreasing exponentially with altitude. This layer is characterized by interaction of high frequency rays with particles to ionize them to ions and molecules. The exosphere plays a crucial role in determining the rate of atmospheric escape, which can affect a planet's atmospheric composition and climate.

The exosphere is affected by space weather events, such as van Allen belt (a dense charged particles layer form during the day due to earth's magnetic field) and coronal mass ejections, which can impact communication and navigation systems.

History of the natural atmosphere

The early Greeks considered "air" not to be mixture of gases but to be one of four elementary substances: along with earth, fire and water. Air was viewed as a fundamental component of the universe. By the early 1800s, however, scientists such as John Dalton recognized that the atmosphere was in fact composed of several chemically distinct gases, which he was able to separate and determine the relative amounts within the lower atmosphere. He was easily able to discern the major components of the atmosphere: nitrogen, oxygen, and a small amount of something incombustible, later shown to be argon.

The development of the spectrometer in the 1920s allowed scientists to find gases that exist in much smaller concentrations in the atmosphere, such as ozone and carbon dioxide. The concentrations of these gases, while small, varied widely from place to place. In fact, atmospheric gases are often divided up into the major, constant components and the highly variable minor components, as shown.

Composition of natural unpolluted air

Permanent Gases	% composition of dry air
Nitrogen (N_2)	78.08%
Oxygen (O_2)	20.95%
Carbon dioxide(CO2)	0.034% or 350ppm
Argon (Ar)	0.90%
Neon, Helium, Krypton	0.0001%
Variable gases	composition in wet air
Water vapor, H_2O	0-4 %
Ozone, O_3	4-65 ppb
Methane, CH_4	1,750 ppb
Carbon monoxide, CO	150 ppb
Nitrous oxide, N_2O all N gases	280 ppb

CHAPTER 4 AIR POLLUTION, CONSEQUENCES AND CONTROL

Pollution is any undesirable change in any part of the environment which has harmful effects, or which unfits that part of the environment for a stated purpose.

Or any change in physical, chemical and biological factors of the environment that have a direct impact on living things.

AIR POLLUTION

"The presence in the outdoor atmosphere of one or more contaminants or combinations thereof in such quantities and of such duration as may be or may tend to be dangerous to human, plant, animal life or property, of which unreasonably interfere with the comfortable enjoyment of life, property or the conduct of business. The Pakistan environmental protection act also define the air pollution as, "Any substance that cause pollution of air includes soot, smoke, dust particles, odor, light, electro-magnetic radiation, heat, fumes, combustion and exhaust gases, noxious gases, hazardous and radioactive substances."

The atmosphere is a dynamic system, which steadily absorbs various pollutants from natural as well as man-made sources thus acting as a natural sink. Gases such as CO, CO_2, H_2S, SO_2, and NO_X, as well as particulate matter, such as sand and dust, are continually released into the atmosphere through natural activities such as forest fires, volcanic eruptions, decay of vegetation, wind, sand and dust storms and also from man-made sources mostly burning of fossil fuels i.e. coal, oil and natural gas. The pollutants emitted directly into the atmosphere by different sources either natural or anthropogenic are called primary air pollutants while pollutants formed because of reactions between primary air pollutants and other elements present in the atmosphere are called secondary air pollutants such as ozone, peroxyacetyl nitrate (PAN).
These have surpassed the pollutants contributed by nature thousand-fold. The magnitude of air-pollution has increased alarmingly due to population explosion, industrialization, urbanization, automobiles and other human proclivities for greater comfort. The pollutants travel through the air, disperse and may interact with other substances in the atmosphere before they reach a sink, such as an ocean or a human receptor. If the pollutants enter the atmosphere at a faster rate than are absorbed by the natural sinks, then they accumulate gradually in the air. Such a disturbance in the dynamic equilibrium in the atmosphere by the air pollutants released by anthropogenic (human) activities resulting in considerable accumulation in the atmosphere may affect the very life on earth and its environment. Further, the dilution and dispersion of gaseous pollutants in the atmosphere depend upon the meteorological conditions prevailing at a given time.

AIR POLLUTANTS AND THEIR EFFECTS

The most common air pollutants are:

1) Oxides of carbon ($COX_)$
2) Oxides of nitrogen ($NO_{X)}$
3) Oxides of Sulphur ($SOX_)$
4) Hydrocarbons (HC, s)
5) Particulates (Dust, aerosols, bacteria etc.).

OXIDES OF CARBON

(1) CARBON MONOXIDE (CO)

The carbon pollution is almost from anthropogenic sources. The ambient air contains under 10ppm of carbon monoxide. Its amount is highly variable in the atmosphere. Although some urban areas may have a level beyond 15 ppm, which is considered as beyond moderate level in pollution index. The natural processes such as marsh gas emissions and electrical discharges in the atmosphere during storms and seed germination can produce some carbon dioxide.

CHARACTERISTICS OF CO

It is a colorless, odorless, toxic gas, slightly water soluble but still it is extremely dangerous because it has a greater affinity for hemoglobin than that of Oxygen (O_2).

CAUSES OF CARBON MONOXIDE

(1) Automobile exhausts

This source accounts for about 60% of CO in the atmosphere.

(2) Forest fires and agricultural burning

Burning of forest debris, crop residue, bushes, weeds and vegetation, which contribute to about 17% of CO in the atmosphere.

(3) Industrial operations

These are electric and blast furnaces in iron and steel industry, petroleum refining, paper industry, gas manufacture and coal mining, which contributes 9.6% of CO in the atmosphere. The concentration of CO in the urban atmosphere is about 55 PPM. Some studies say that transportation accounts for about 74% of the entire global CO emissions, out of which major contribution comes from gasoline feed internal combustion engines. Lot of attention and efforts has been directed towards controlling CO from the sector.

BIOLOGICAL EFFECT OF CO

It competitively inhibits combination of O_2 and hemoglobin. It attacks hemoglobin and displaces O_2 to form carboxyhemoglobin and thus reduces the oxygen carrying capacity.

In the presence of CO

$O_2Hb+CO \rightarrow COHb + O_2$

The immediate response to CO poisoning is loss of judgment, which is responsible for many automobile accidents. further exposure to higher levels of CO leads to various metabolic disorders such as asphyxiation and causes death.CO poisoning can be cured by providing fresh O_2, which reverses the above reaction.

OXIDES OF NITROGEN (NOX'S)

Out of the eight possible oxides of nitrogen, only nitric oxide (NO), Nitrous oxide (N_2O) and nitrogen dioxide (NO_2) are 0.25 ppm, 0.1 to 2 ppm and 0.5 ppm respectively. Although the concentration of N_2O is more in the atmosphere, NO_2 and NO are more significant from air pollution point of view, and they are usually represented together as NOx's. The formation of NO from N_2 and O_2 is favored at high temperature (~1210 to 1765℃), which are usually attained in the combustion processes involving air. Rapid cooling of the combustion products (quenching) prevents the dissociation of NO. The oxidation of NO to NO_2 is also favored at high temperature ((~1100℃), but the amount of NO_2 formed is usually not more than 0.5% of the total NOx's present. Because of some Photochemical reactions, the radiation split the nitrogen dioxide back to primary pollutant nitric oxide (NO). The formation of NO from N_2 and O_2 is in the first step. NO_2 is also formed by photolytic reactions in the atmosphere. These reactions are given as

$N_2 + O_2 \,(1210-1765C^{\circ}) \rightarrow 2NO$

$2NO + O_2 \,(1100C^{\circ}) \rightarrow 2NO_2$

$NO_2 + HV\ (398\ nm)\ near\ visible \rightarrow NO + [\dot{O}]\ very\ reactive$

$O_2 + HV\ (242nm)\ uvb \rightarrow [\dot{O}] + [\dot{O}]$

$[\dot{O}] + O_2 + M^* \rightarrow O_3\ (Ozone)$

$O_3 + NO \rightarrow NO_2 + O_2$

$2NO_2 + O_3 \rightarrow N_2O_5 + O_2$

$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$ NITRIC ACID

Alternative mechanism for nitric acid formation

$O_3 + NO_2 \rightarrow NO_3 + O_2$

$NO_3 + NO_2 \rightarrow N_2O_5$

$N_2O_5 + H_2O \rightarrow 2HNO_3$

As a result of the above reactions, oxides of nitrogen are formed mostly in combustion engine of automobiles. Oxides of nitrogen may be formed either by the natural or artificial fixation of nitrogen from the atmosphere or from nitrogen compounds present in organic matter. The annual global release of NO_x from manmade sources is about 5×10^7 tones, which is slightly less than that of coal, oil, and natural gas and other organic matter. Thus, NOX are introduced into the atmosphere from automobile exhausts, incinerators, furnace stacks, coal-based power plants and other similar sources.

When fuels are burnt in the air, some of the molecular nitrogen in the air is oxidized to NO. The amount of NO formed depends on the temperature of the furnace and the rate of cooling and quenching of the combustion products. Higher flame temperatures and rapid cooling of the combustion products favor the formation of NO.

The average residence time of NO and NO_2 in the atmosphere are four days and three days respectively. They undergo various photochemical and chemical reactions in the atmosphere leading to the formation of HNO_3, which gets precipitated as dry deposition or wet deposition also called acid rain. The nitrogen oxides from anthropogenic sources may be 10 to 90 times more in urban as compare rural areas. Even in any area (rural or urban), the amount of NOx levels varies with sunlight and traffic density at any given point of time. Chemical and photochemical reactions involving nitrogen dioxide and hydrocarbons induced by sunlight are responsible for the formation of peroxyl acetyl nitrate which led to photochemical smog.

Catalytic converter as pollution control technology

Use of two stage catalytic converters can reduce the nitrogen oxides and other air pollutants from automobile emissions as under

$NO_X \rightarrow N_2 + O_2$

Hydrocarbons (HCS) to CO_2 and H2O

Control of NO_x in power plant

Oxides of nitrogen can be reduced 90 % by using two-stage combustion process. The fuel can be fired at a high temperature using only about 90 % stoichiometric air required so that only minimum quantity of nitric oxide is formed.

In the second stage the combustion of fuel with low temperature and excess air is completed. nitric oxide (NO) is not formed under these conditions.

CHARACTERISTICS OF NOX_{ES}

NO_{XS} mostly comprises NO, NO_2 and N_2O. Nitric oxide is a colorless gas and is slightly soluble in water. Nitrogen dioxide ($NO_{2)}$ is reddish brown gas, sometimes called brown haze in pollution context, somewhat soluble water oxidizing agent, can react with water to form nitric acid, which is power full oxidizing agent and capable of reacting with almost all metals and organic compounds. NO_2 can travel into the respiratory system. It is also involved in the formation of pollutant ground level ozone.

BIOLOGICAL EFFECTS

Oxidizes cellular lipids forms bonds with hemoglobin and reduces the efficiency of oxygen transport, disrupt some cellular enzymes system, higher level and prolonged exposures may cause pulmonary fibrosis, inflammation of lung tissues and may lead to death. causes nitric acid mediated effects, some of which are like that of sulfuric acid. Nitric oxide can form additional compounds with hemoglobin, if it enters the blood stream.

Oxides of Sulphur (Sox)

Combustion of any Sulphur-bearing materials produces SO_2 accompanied by a small quantity of $SO_{3.}$ This mixture is usually denoted as NO_X. Nearly 67% of the global SO_X pollution is due to volcanic eruption and other natural sources, over which we have no control. The remaining 33% SO_2 emission is because of human activities such as combustion of fuels, coal fired power stations, transportation, refineries, metallurgical operations such as smelting of sulfides ores and chemical plants e.g. manufacturing of sulfuric acid.

Most of the manmade SO_X pollution is concerned in urban and industrial areas. Almost all the Sulphur present in liquid and gaseous fuels and about 80% of the Sulphur present in the solid fuels appear as SO_X in the flue gases, depending on the percentage of excess air used. The concentration of SO_2 in flue gases varies from 0.04 to 0.4%. In the atmosphere by catalytic processes involving ozone, NOx and hydrocarbons giving rise to the formation of smog. Oxidation of Sulphur dioxide can take place in the presence of catalysts such as NO_X, metal oxides, soot and dust.

Under normal humid conditions of the atmosphere, SO_3 reacts with water vapors to produce droplets of sulfuric acid aerosols, which may be deposited called wet deposition. The sulfuric acid and sulphate aerosols present in the urban air are smaller than 2 micron(μ) and hence can easily reach the pulmonary region of lungs causing serious respiratory problems particularly in old people.

(1) $SO_2 + O_3 \rightarrow SO_3 + O_2$

$SO_3 + H_2O \rightarrow H_2SO_4 \rightarrow (2\ H_2SO_4)_n$

The following reaction is always carried in the presence of catalysts

(2) $SO_2 + ½\ O_2 + H_2O$ metal oxides, soot H_2SO_4 aerosol $(H_2SO_4)_n$

CHARACTERISTICS OF OXIDES OF SULPHUR

SO_X comprises of SO_2 (97% to 99%) and SO_3 (1-3%). It is colorless, heavy, water-soluble gas with pungent and irritating odor. Rapidly diffusing, acid forming, oxidizing agent. reacts with organic matter, metals and materials.

BIOLOGICAL EFFECTS

Absorb quickly and irritate the upper respiratory track. Reacts with cellular constituents, chemicals e.g. Enzymes. The sulfuric acid formed lowers P^h, impairs enzymatic activity and destroys various function molecules, lead to the bronchial spasms, breathlessness, impaired pulmonary function via airway resistance, impaired lungs clearance and increased susceptibility for infection.

REMOVING SO_X FROM FLUE GASES

Before letting them out into the atmosphere chemical scrubbers such as limestone ($CaCO_3$) and citric acid are suggested to absorb Sulphur dioxide (SO_2) from flue gases.

a) $CaCO_3 + SO_2 + ½\ O_2 \rightarrow CaSO_4 + CO_2$

b) $SO_2 + H_2O \rightarrow HSO^-_3 + H^+$

$HSO^-_3 + (H_2\ cit^-)$ citric acid$\rightarrow (HSO_3 . H_2\ cit)^{-2}$

REMOVING SULPHUR FROM FUELS USED FOR COMBUSTION

Pyritic Sulphur in coal can be removed by grinding and washing in coal washers. However originally bounded Sulphur cannot be easily removed from coals. Research is in progress to

synthesize special types of microorganisms using biotechnology, which can convert organically bound Sulphur into soluble forms.

2) Utilizing low Sulphur fuels.
3) Generation of power by alternative energy sources and discouraging fossil fuels based thermal power plants.

HYDROCARBONS

Hydrocarbons are emitted into the atmosphere by natural biological activity as well as anthropogenic sources such as automobile exhaust, burning of coal, oil, wood, refuse and solvent evaporation. Anthropogenic sources account for about 15% of the total HC's emissions into the atmosphere. the annual global hydrocarbon emissions to the atmosphere by manmade source is roughly estimated to be 57×10^7 tons per year.

Methane is the major hydrocarbons emitted into the atmosphere by natural activities such as anaerobic decomposition of organic matter in water, soil and sediments by microorganism.

PARTICULATE MATTER

The nongaseous part of pollutants is called particulates. They are larger particles as compared to gases. These particles are aerosols, fumes, dust and bacteria. There are two types of particulates, the PM-10 micrometer and PM- 2.5 micrometers. Sometimes people cannot differentiate between gaseous pollutants and particulates. Particulates have larger sizes, some of them can be controlled through face mask while gaseous pollutants are inhalable and cannot be controlled through mask. Particulates of ten (10) micrometers are not so dangerous as compared to 2.5. Particulate matter of 2.5 micrometers is highly carcinogenic like soot also called black carbon. These particles can cause both short-term and long-term disorders l such as asthma, chronic obstructive pulmonary diseases, cardiovascular disorders, lungs cancer, neurological effects such as Alzheimer's and Parkinson's. Effects of disorders may vary with the nature of particles. Inhalation of dust mostly Carbon particles sometimes cause scarring of lungs through complex walling off leading to the conditions known as pneumoconiosis, particles absorbed into mutagens lead to damage DNA in severe cases.

AIR QUALITY INDEX

The Air Quality Index (AQI) measures air pollution levels, indicating potential health risks. The air pollution index is designed to present air quality information in an easily understandable way. AQI is based on guidelines set by various organizations, including United States environmental protection agency's (US-EPA) world health organization (WHO), central pollution control board of India (CPCB). All these organizations use AQI and Nowcast guidelines. Nowcasting is the description of the current state of the weather and prediction of changes that can be expected on a time scale of few hours. key differences among them are the pollutants averaging periods. It converts the concentrations of various

air pollutants at a given location into a single number, ranging from zero (0) for clean air to five hundred (500) plus for heavily polluted air.

This number is classified into one of six color-coded categories, each associated with different health recommendations, IQ Air calculate using hourly concentration averages, offering more timely air quality information than the standard twenty-four (24) hours average as compared to U.S. AQI or the Nowcast AQI. The values, categories and cautionary statements of IQA, U.S.AQI align with those of the U.S. EPA, assuming pollution levels remained constant for the specified averaging period.

AQI CATEGORIES

Good (0-50): Air quality is satisfactory, posing little or no risk. Ventilating your home is recommended.

Moderate (51-100): Air quality is acceptable, but sensitive individuals may experience mild discomfort. Sensitive individuals should limit outdoor activity and go inside if experiencing respiratory symptoms such as coughing or shortness of breath.

Unhealthy for Sensitive Groups (101-150: Members of sensitive groups may experience health effects. Some members of the public and all sensitive groups are at risk of health effects and should avoid outdoor activities if experiencing irritation or respiratory symptoms.

Unhealthy (151-200): increased likelihood of adverse effects and aggravation to the heart and lungs among general public- particularly for sensitive groups. Consider all activities inside.

Very Unhealthy (201-300): Health warnings of emergency conditions, general public will be noticeably affected. Sensitive groups will experience reduced endurance in activities. These individuals should remain indoors and restrict activities.

Hazardous (300 plus): Health alert, everyone may experience serious health effects. General public and sensitive groups are at high risk to experience strong irritations and adverse health effects that could trigger other illnesses. Everyone should avoid exercising and remain indoors.

AQI PARAMETERS

The AQI is based on measurements of:

Particulate Matter (PM2.5 and PM10):

Particulate Matter (PM) is typically measured in micrograms per cubic meter (µg/m³), not parts per million (ppm). Here's the breakdown for PM2.5 and PM10:

PM2.5 (Particulate Matter ≤2.5 µm)

Low (Good): 0-12 µg/m³ (AQI 0-50)

- Moderate: 13-35 µg/m³ (AQI 51-100)

- High (Unhealthy): 36-55 µg/m³ (AQI 101-150)

- Severe (Very Unhealthy): 56-150 µg/m³ (AQI 151-200) or higher

PM10 (Particulate Matter ≤10 µm)

- Low (Good): 0-54 µg/m³ (AQI 0-50)

- Moderate: 55-154 µg/m³ (AQI 51-100)

- High (Unhealthy): 155-254 µg/m³ (AQI 101-150)

- Severe (Very Unhealthy): 255-354 µg/m³ (AQI 151-200) or higher

CARBON MONOXIDE (CO)

Carbon monoxide levels in the Air Quality Index (AQI) vary by country or region. There are common standards set by world quality organizations. This must be under consideration that these guidelines are in general category and are not for specific organizations.

Low (Good): from 0-9 ppm is an acceptable level over 8 hours, according to WHO and US EPA.

Moderate: according to US- EPA and WHO, from 9-35 ppm may cause health concerns for sensitive individuals over 1-8 hours. Occupational Safety and Health Administration (OSHA) standard is 50 ppm (8-hour time-weighted average).

High (Poor): 200 ppm or greater may cause physical symptoms and be fatal in hours. according to American Conference of Governmental Industrial Hygienists (ACGIH) that Up to 400 ppm is high short-term exposure limit and 800 ppm or greater is fatal within minutes.

OZONE (O3)

Ozone (O3) levels in the Air Quality Index (AQI) are typically measured in parts per billion (ppb). Ozone (O3) Levels in air quality are given below.

Low (Good): 0-54 ppb (AQI 0-50) have Little to no health risk.

Moderate: 55-70 ppb (AQI 51-100) is unusually sensitive and has mild respiratory issues.

High (Unhealthy for sensitive groups): 71-85 ppb (AQI 101-150) have respiratory issues (coughing, wheezing) in sensitive groups (children, asthmatics, elderly).

Very High (Unhealthy): 86-105 ppb (AQI 151-200) have respiratory issues in general population; more severe effects in sensitive groups.

Extremely High (Very Unhealthy): 106-200 ppb (AQI 201-300) or higher have Serious respiratory issues; potential for reduced lung function and other health problems. In severe cases, it may cause pulmonary Edema; a condition in which after inhalation and absorption

in the lungs, it can cause accumulation of fluids in the lungs damaging lungs capillaries and death may occur. It may inhibit the activity of some enzymes in plants involved in synthesis of cellulose and lipids.

NITROGEN DIOXIDE (NO2)

Nitrogen dioxide levels in the air quality index are categorized based on their potential health effects. Here's a breakdown [1]:

Good (0-50 AQI): Little to no health risk from nitrogen dioxide exposure. The air quality is satisfactory.

Moderate (51-100 AQI): Some individuals unusually sensitive to air pollution might experience minor health concerns.

Unhealthy for Sensitive Groups (101-150 AQI): People with respiratory issues, like asthma, may experience health effects. General public isn't likely to be affected.

Unhealthy (151-200 AQI): Everyone might experience some adverse health effects. Sensitive groups may face more serious issues.

Very Unhealthy (201-300 AQI): Health alert for everyone. The entire population is at risk of experiencing significant health effects.

Hazardous (301-500 AQI): Emergency health warnings. The entire population is at risk of severe health effects. Outdoor exposure should be avoided.

Major Disorders Associated with NO2 Exposure are Respiratory problems (asthma, bronchitis), Increased susceptibility to respiratory infections, Reduced lung function Cardiovascular issues (e.g., heart attacks, strokes). Higher levels and prolonged exposures may cause pulmonary fibrosis, inflammation of lungs tissues and may eventually lead to death.

SULFUR DIOXIDE (SO2)

Sulfur Dioxide (SO2) levels in the Air Quality Index (AQI):

Good (0-75 ppb): Little to no health risk

Moderate (76-150 ppb): Respiratory issues in sensitive individuals.

Unhealthy for sensitive groups (151-300 ppb): Respiratory problems such as bronchospasm.

Unhealthy (301-500 ppb): Respiratory issues, reduced lung function.

Very unhealthy (501-1000 ppb): Serious respiratory issues.

Hazardous (1001 ppb or higher): have severe health risks.

Prolonged exposure can cause respiratory problems such as asthma, bronchitis, bronchospasm and increased susceptibility to respiratory infections Sensitive individuals,

such as children, the elderly, and those with respiratory or cardiovascular problems are typically the first group affected by poor air quality. High AQI levels can cause respiratory issues, organ damage, and other health problems.

Someone can check real-time AQI data on websites like World Air Quality Index or AQI, at which the air quality conditions and forecasts are given for hourly, daily and monthly basis. The annual air quality report is also given for locations worldwide.

PAKISTAN'S AQI

According to air quality index repots 2024, Pakistan global ranking in air pollution is 3rd out of one thirty-eight (138) countries. Pakistan's national average AQI in 2024 was approximately 115, categorizing the air quality as "moderate to poor" with occasional hazardous peaks, particularly in urban centers like Lahore and Karachi.

The country's PM2.5 annual average concentration was73.71 μg/m³ which was about 14.7 times higher than the World Health Organization's annual guideline value of 5 μg/m³, highlighting severe air pollution concerns. In 2024, Pakistan faced significant air quality challenges, with major cities frequently experienced pollution levels that were far exceeded international safety standards. The Air Quality Index (AQI), which measures pollutants like PM2.5, PM10, NO_2, SO_2, CO, and O_3, indicated widespread air quality issues across the country.

Following is the air pollution index annual as well as daily data of metropolitan cities of Pakistan. The particulate matter of both types is in unsafe category. Compared with standards of WHO and U.S-EPA, even the moderate AQI range may be unsafe for long-term exposures especially for sensitive groups, While the other gaseous air quality parameters are almost within safe range. The measurements of gaseous parameters are on daily basis because they are changing in hours and have a great influence in concentration with traffic density, industries, urban and rural areas. This data is the ambient air data of these cities and are not considered for specific organizations as they may have high pollution range.

#	Location (city)	average AQI	PM 2.5 µg/m³	PM 10 µg/m³	AQI Status **(Annual)**	CO (ppb)	O_3 (ppb)	SO_2 (PPb)	NO_2 PPb
1	Islamabad	102	36	100	poor	451	47	4	6
2	Lahore	158	62	186	Unhealthy	737	32	6	32
3	Karachi	111	40	89	poor	428	27	5	14
4	Peshawar	73	21	46	moderate	294	41	4	10
5	Multan	2135	947	N/A	Hazardous	365	67.9	4.77	1.93
	WHO2021 **(24hrs).**	N/A	≤15	≤45	Unsafe	Almost Safe **(24 hrs.)**			
	Annual recommendations	N/A	≤5	≤15	Unsafe				
	Daily status					good	good	Good	good
	WHO 2021 recommendation **24 hrs.**				5,000-6,000 ppb 5-6ppm		50-60 Ppb (max **8*hrs**.	7-20 Ppb	25 ppb

CONSEQUENCES OF AIR POLLUTION

The current environmental challenges are mostly the consequences of air pollution. Here are some major environmental issues due to air pollution.

ACID RAIN

Rain is naturally acidic in nature, because carbon dioxide is naturally present in the atmospheres, which react with water to form carbon dioxide as following

$CO_2 + H_2O \rightarrow H_2CO_3$ (carbonic acid)

The natural pH of rain is (5.6) but this is not the acid rain. When rainwater passes through the atmosphere polluted with oxides of Sulphur and nitrogen, the falling rain and snow react with these oxides and pollutants to produce often a mixture of sulfuric acid, nitric acid and water. In polluted atmosphere certain reactions produce acids, which lower the PH from 5.6 to more acidic. NO_X high concentration mostly in urban areas follows the following reactions.

$NO + HO^{\bullet} \rightarrow HNO_2$

$NO_2 + HO^{\bullet} \rightarrow HNO_3$

We can reduce this pollution by adopting catalytic converters in vehicles.

$SO_{X,}$ which are more soluble in rainwater, produces sulfuric acid as

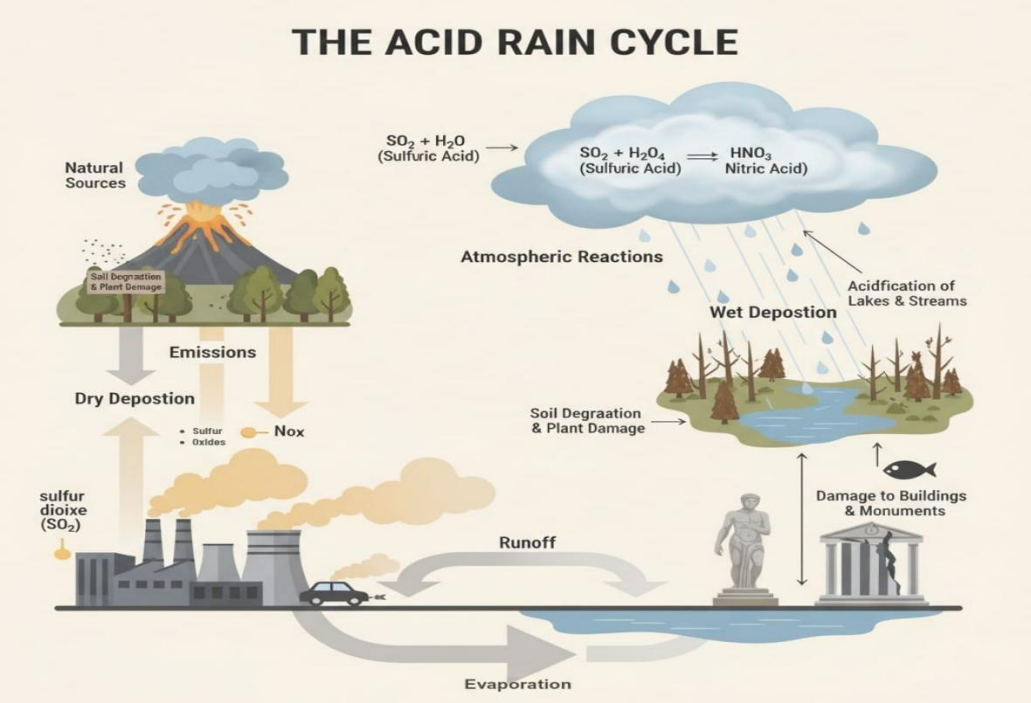
$SO_2 + H_2O \rightarrow H_2SO_3$

$SO_3 + H_2O \rightarrow H_2SO_4$

Hydrocarbons can produce acids by following reactions in the atmosphere

$SO_2 + HO^{\bullet} \rightarrow HSO_3^-$

$HSO_3^- + HO^{\bullet} \rightarrow H_2SO_4$



Lose Angeles acid rain as a case study

The Acid rain had first occurred in Lose Angeles with pH 3.0 to 2.0: equal to pH of vinegar or lemon. Acid rain may occur at a place far away, may even 500 to 1000km from the source of pollutants. Some events of acid rainfall in Sweden and Canada have been traced to be due to large scale SO_x emissions from densely polluted industrial areas of United Kingdom and the United States.

Effects of the acid rain

Acid rain may Cause extensive damage to materials and terrestrial ecosystems such as water, fish, vegetation, stone, steel, paint, soil and mankind as fallowing.

1) Damage to buildings and structural materials as well as valuable ancient sculptures, carved from marble, limestone, sandstone etc.
2) Acidification of soils with consequent effects on microbial and soil fauna and fixation of nitrogen.
3) Foliar damage to crops and forests, leaching of nutrients from leaves and alteration of seed germination.
4) Potential effects on aquatic systems such as acidification, decreased alkalinity and mobilization of materials like aluminum.
5) Other biological effects on aquatic biota such as altered species composition among plankton, vegetation and invertebrates.
6) Decline in productivity of fish and amphibian, skeletal deformation and increased fish mortality.
7) Corrosive damage to steel, zinc, oil-based paints and automobiles coatings.
8) Possible effects on human lungs, skin, and hair may be affected.
9) The heavy metals released by acid rain also may cause potential threats to human health.

10) Acidification of drinking water reservoirs and concurrent increase in heavy metals concentration may exceed public health limits and may cause health concerns.
The extent of acid rain depends upon factors such as climate, topography, geology, biota and human activity.

Lapse rate

"The change in the temperature of an air parcel in the atmosphere with altitude is called lapse rate." The atmosphere works on Joule Thomson affect. According to the Joule Thomson affect "when a gas that is free to expand, has a tendency to move from high pressure region to low pressure region, while doing so, the gas expands and if there is no opportunity to exchange its heat with the surrounding, the gas undergoes adiabatic cooling."

The adiabatic lapse rate can be calculated with the help of pressure-volume-temperature relationship, the adiabatic expansion and the change of pressure with altitude. The value for adiabatic lapse rate has been calculated about -10° C/km for dry air and about -6° C/km to -7°C/km for humid air. Under conditions of adiabatic lapse rate, a smoke flume rises upwards into the atmosphere by virtue of its low density (because of its higher temperature, until it reaches air of similar temperature and similar density. However, in many practical situations, the lapse rate is found to be either greater or lesser than that of the adiabatic lapse rate due to external heating and cooling effects. From air pollution point of view, the following two situations are of great importance.

Super adiabatic lapse rate

On a clear summer day, the air near the earth's surface gets heated rapidly to reach a condition where the lapse rate is super adiabatic. In such a situation, the atmosphere is said to be in an adiabatic equilibrium. It is under such conditions when the atmospheric pollutants are dispersed due to considerable vertical mixing of air.

TEMPERATURE INVERSION (NEGATIVE LAPSE RATE)

When the temperature increases with increasing altitude, inversion occurs in the atmosphere mainly due to the following two reasons:

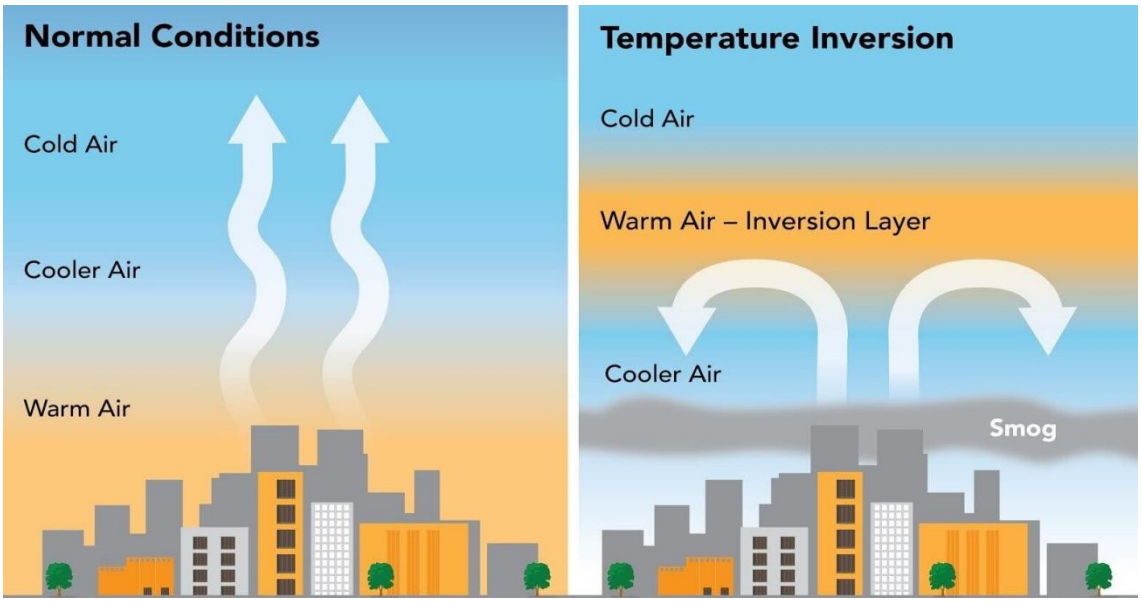
Radiation inversion

Such a situation occurs when the air near the ground or earth's surface gets cooled because of heat loss by the earth at night by emitting long wave or infra-red radiation. Under the conditions of temperature inversion, the air near the ground is denser than the air above and hence very little mixing or turbulence takes place.

Subsidence inversion

Such a situation occurs when the upper layer of air subsides (i.e. descends) during a developing anticyclone (i.e. high-pressure center). This subsiding air warms at its contract, but the extent of warming will be greater at the upper part than at the lower part near the ground.

Under the conditions of inversion, the denser cold air at the bottom cannot rise due to lack of any driving force and the atmosphere is said to be stable. Such a situation is dangerous from the atmospheric pollution point of view because the pollutants in the air cannot be dispersed. Development of inversion conditions generally occurs on calm and clear nights, when the ground is strongly cooled. Hence, the air near the ground level is also cooled, while the air above is relatively warm. In such a condition, if a pollutant is discharged at or near the ground level, the pollutants tend to concentrate rather than getting dispersed in the air. This increasing tendency of air pollution may lead to disastrous consequences. Inversions generally can be destroyed by the next morning due to solar heating of the ground and buildings which enable upward current of the warm air. Simultaneous occurrence of mist or fog may prolong the duration of inversion by reducing the sunlight reaching the ground. The problem of air pollution creates serious dimensions under conditions of inversion and other meteorological conditions, which are adverse to the effective dispersion of pollutants.



Inversion is responsible for many air-pollution episodes in the world. The notorious London smog of 1952 that lasted for five days killing four thousand people is an example. In towns and villages which are situated in valleys, inversion conditions are particularly disastrous, because the dense air charged with pollutants descends to the valleys and form a sort of "lake of polluted air."

Temperature inversions that occur aloft can cause convective clouds to spread out. One example is the flattened tops of the towering storm clouds, they reach the top of the troposphere. When stable air is forced aloft, the associated clouds generally have little vertical thickness and precipitation. In contrast, unstable air can result in towering clouds frequently accompanied by thunderstorms and heavy precipitation.

SMOG FORMATION

There are two types of smog

REDUCING/ INDUSTRIAL OR LONDON SMOG

Reducing agents like SO_2, CO, Soot are present in this type of smog as these are strong reducing agents, which get oxygen from other agents because of shortage as follows

$SO_2 + ½ O_2 \rightarrow SO_3$

$CO + ½ O_2 \rightarrow CO_2$

$C + O_2 \rightarrow CO_2$

As these gases come out from industrial processes mostly by the combustion of fossil fuels, so called industrial smog. Small amounts of nitrogen oxides, hydrocarbons and other are also present. This smog is mostly occurring in temperature inversion conditions.

Effects of these reducing agents

In a long-term inversion condition with no atmospheric turbulence, Sulphur dioxide can react with water forming a weak sulfuric acid resulting in acid rain.

$SO_3 + H_2O \rightarrow H_2SO_4$

Carbon monoxide causes respiratory problems and blood diseases because of lack of oxygen. It also causes fatigue, headache, nausea and vomiting. Soot on the other hand causes lungs problems like cancer.

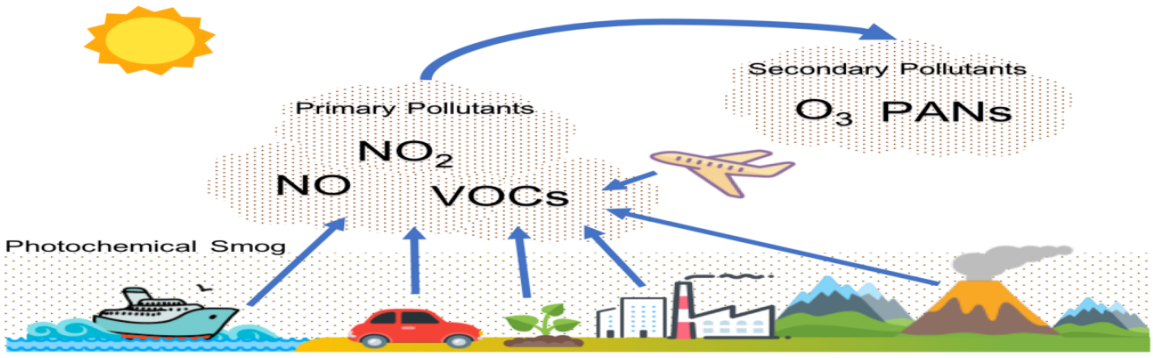
London smog: as case study

From 5 to 9 december1952, London experienced such smog. Four thousand people had died, and many were hospitalized. Smog fleet from Friday to Sunday. Many people were hospitalized, Sunday started, and death occurred. On Monday active and heavy winds pick the temperature inversion (pollutants) and air currents started. Four days incident caused four thousand deaths. This disaster led to major environmental reforms, including “the Clean air act of 1956” in the UK.

(2) PHOTOCHEMICAL/ OXIDIZING OR LOS ANGELES SMOG

When the atmosphere(troposphere) is loaded with large quantities automobile exhausts during warm sunny days with gentle winds and low level inversion, then exhaust gases are trapped by inversion layers with stagnant air masses and simultaneously exposed to intense sunlight, then a number of photochemical reactions involving nitrogen oxides, hydrocarbons, other organic compounds , free radicals(methyl, ethyl) take place leading to formation of ground level ozone, per oxides and other photochemical oxidants in the

atmosphere. This gives rise to the phenomenon of photochemical smog. This smog is characterized by the formation of aerosols that reduce visibility, generation of brown haze fumes.



The compounds of this smog (mostly PAN and ozone) are oxidizing in nature so called oxidizing smog. The reactions and radical formation are as follows.

Reaction 1

$NO_2 + HV\,(A) \rightarrow NO + O^{\bullet}$

$O_2 + O^{\bullet} + M^{*} \rightarrow O_3 + M^{*}$

$NO + O_3 \leftrightarrow NO_2 + O_2$

Reaction2

RH (hydrocarbon) + $O^{\bullet} \rightarrow RHO^{\bullet}$ (Methyl or ethyl radical)

$CH_3^{\bullet} + O_3 \rightarrow H_3COOO^{\bullet}$ (ethyl peroxyl radical)

$H_3C{-}H_2C^{\bullet} + O_3 + \frac{1}{2}\,O_2 \rightarrow H_3C{-}COOO^{\bullet} + H_2O$ (ethyl peroxyl radical)

The nitrogen dioxide from equ1 and ethyl peroxide from equ2 will react for the formation of peroxyl acetyl nitrate (PAN).

$H_3C{-}COOO^{\bullet} + NO_2 \rightarrow H_3C{-}COO{-}NO_3$ (peroxyl acetyl nitrate)

Effects

The brown haze fumes that irritate the eyes and lungs and cause extensive damage to vegetation and rubber goods. This smog was first observed in 1940 in Los Angeles and Denver in the USA.

Control

In the first control method of photochemical smog, we must control the emissions of primary pollutants like oxides of nitrogen and hydrocarbons.

Secondly, we must use catalytic converters in vehicles to control air pollution and smog formation. The catalytic converter will convert the pollutants to less hazardous or no toxic ones.

SMOG ISSUE IN PAKISTAN

Smog is a specific type of air pollution created by a mixture of pollutants, such as nitrogen oxides, Sulphur dioxide, and particulate matter, which reacts with sunlight and heat to form a thick, hazy mixture.

Smog, one of the most common environmental issues in Pakistan, is most commonly seen in large cities, particularly those with high levels of industrial activity. Smog episodes in Pakistan have become a critical environmental and public health issue, particularly in urban areas and can adversely affect human health and the environment. Some of these include respiratory problems, eye irritation, and decreased visibility.

Smog is typically measured by monitoring the levels of various pollutants in the air. Several methods exist, including continuous monitoring stations, mobile monitoring units, passive samplers, and satellite observations. The measurement data collected by these methods are used to calculate an Air Quality Index (AQI), a scale used to communicate the level of air pollution to the public.

causes of smog in Pakistan

Agricultural Burning

The practice of burning crop residue in fields after harvest is a common cause of smog in Pakistan. The burning releases harmful pollutants into the air, which contributes to the thick haze seen in many parts of the country.

Industrial Emissions

Industries in Pakistan, particularly those in the manufacturing and energy sectors, emit a large number of pollutants into the air. These pollutants, such as carbon monoxide and Sulphur dioxide, contribute to the smog problem in the country. The industrial sector contributes 24% to smog formation in Punjab, 9% in Lahore, and 8% in Peshawar.

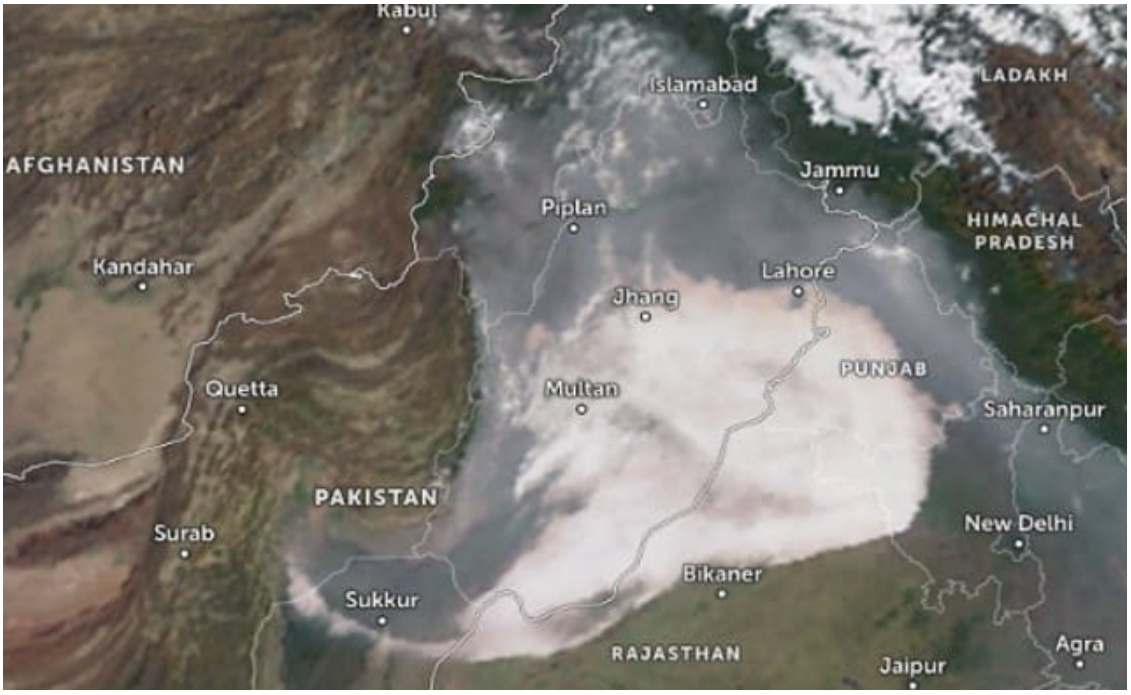
Vehicular Pollution

The increasing number of vehicles on the roads in Pakistan is a major contributor to air pollution and smog. Vehicles emit harmful pollutants, such as nitrogen oxides and particulate matter, which contribute to the thick haze seen in many cities. The transport

sector is a major contributor to smog formation, accounting for 39% of smog in Punjab, 83.5% in Lahore, and 84.5% in Peshawar.

Construction Activities

Dust generated by construction activities and roadways, as well as industrial and vehicular emissions, contribute to the smog problem in Pakistan. Dust particles can become trapped in the atmosphere, leading to reduced visibility and poor air quality.



OZONE LAYER DEPLETION

The formation of ozone layer in stratosphere is already discussed in the atmosphere chapter. here we will discuss the ozone layer depletion trough different pollutants.

Reaction with nitric oxide (NO): in the atmosphere, nitric oxide comes from chemical reactions in heat engine and from photochemical reactions, supersonic jets and nuclear explosions.

$O_3 + NO \rightarrow NO_2 + O_2$

Ozone is depleted to nitrogen dioxide and molecular oxygen.

Reaction with atomic oxygen: atmospheric atomic oxygen, which is highly energetic for reaction comes from splitting of molecular oxygen, which is required for ozone depletion.

$O_3 + O^{\bullet} \rightarrow O_2 + O_2$

Depletion (reaction) through hydroxyl and per hydroxyl ($HOO^{\bullet}$) radicals

Hydroxyl ions in the atmosphere come from biomass burning and from natural water and moisture present, which split the water molecule through sunlight.

$O_3 + HO^{\bullet} \rightarrow O_2 + HOO^{\bullet}$

$HOO^{\bullet} + O^{\bullet} \rightarrow HO^{\bullet} + O_2$

it is estimated that one molecule can destroy a hundred molecules of ozone. Hydroxyl ion formed in the second reaction will deplete more and more ozone molecules.

Depletion of ozone by chlorofluorocarbons (CFC's)

Ozone in the stratosphere is also found to be destroyed by man-made chlorofluorocarbons (CFCs), which are used as coolants in refrigerators, air conditions, and propellants in aerosol sprays and in plastic foams, such as "thermo Cole or Styrofoam". the CFC molecules, escaping into the atmosphere to release chlorine in the ozone layer (by photo-dissociation) and each atom of chlorine, thus liberated in capable of attacking several ozone molecules. The CFCs, most of them chlorine and fluorine, also come from volcanic eruptions, also depleting the ozone layer.

i. $Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet}$
ii. $ClO^{\bullet} + O^{\bullet} \rightarrow Cl^{\bullet} + O_2$

and

iii. $Fl^{\bullet} + O_3 \rightarrow FlO^{\bullet}$
iv. $FlO^{\bullet} + O^{\bullet} \rightarrow Fl^{\bullet} + O_2$

The chlorine atom used to deplete ozone molecules regenerated in the second reaction, so that a long chain reaction is involved, which conserves chlorine atoms.

Case study: Southern ozone hole

The environmental hazards of CFCs were recognized as early as 1970. In fact, temporary thinning of the stratospheric ozone layer, leading to the formation of ozone hole. The hole was first detected over Antarctica during September to November in 1985. Reports increased in case of skin cancer in South Australia were also attributed to U.V radiations reaching the earth due to depletion of ozone layer, over that part the world temporarily.

The detection of the "Ozone hole" over Antarctica in 1985 attracted the attention of scientific community in the world. The U.S immediately banned the use of CFCs in sprays and cans. Further in the year 1987, twenty-four nations of the world signed the Montreal protocol, which aims at 35% reduction in the global production of the CFCs by the year 1999. Simultaneously, efforts to produce chlorine-free substitutes have also started. In fact, synthesis of a product called "HFC-134a" has already been reported as an affective substitute for CFCs. The use of hydro fluorocarbons (HFCs), hydrocarbons, hydro chlorofluorocarbons (HCFCs) and methyl cyclohexane (MCH) as substitutes for CFCs is envisaged for several applications.

According to NASA studies and data, here is a summary of the ozone layer hole situation during the fast specific years and future recovery projections.

1971: No significant ozone layer depletion was observed, as the harmful effects of chlorofluorocarbons (CFCs) and other ozone-depleting substances (ODS) had not yet become apparent.

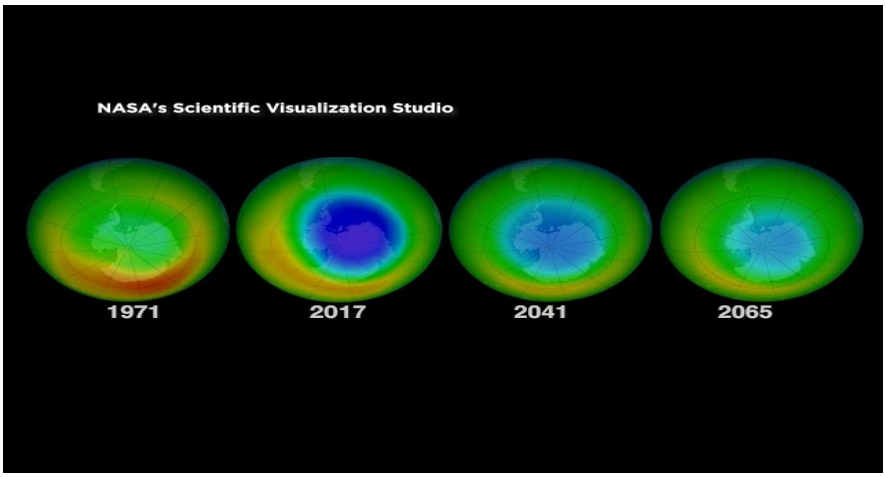
2017: The ozone layer hole over Antarctica reached a size of around 7.6 million square miles (19.6 million square kilometers), with a minimum ozone concentration of 114 Dobson Units (DU). While still significant, this was smaller than the record-breaking hole in 2000.

RECOVERY PROJECTIONS

2041: NASA simulations suggest that the ozone layer hole will continue to recover, with a predicted size of around 4.8 million square miles (12.4 million square kilometers) and a minimum ozone concentration of 140 DU.

2065: Further recovery is expected, with a predicted ozone layer hole size of around 2.5 million square miles (6.5 million square kilometers) and a minimum ozone concentration of 170 DU.

Please note that these projections are based on simulations assuming continued compliance with the Montreal Protocol, which regulates ODS emissions. Actual results may vary depending on various factors, including future emissions and climate change.



Source: NASA's Ozone Hole Watch and scientific studies published in the Journal of Geophysical Research.

CHAPTER 5 BIODIVERSITY AND CONSERVATION

INTRODUCTION

The term biodiversity was coined by R.F. Dasmann in 1968. Biodiversity is formed from two words bio means "biological" and diversity means varieties. It refers to the variety and abundance of living organisms living in a particular region.

The Pakistan environmental protection act, 1997 also define the biodiversity as "the variability among living organisms from all sources, including inter alia terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part, including diversity within species, between species and ecosystems."

IMPORTANCE OF BIOLOGICAL DIVERSITY

Biodiversity has significance for the survival of human beings and the existence of flora and fauna. Biodiversity provides many direct and indirect benefits to humanity. For example, provide food, fuel wood, raw materials for industries and materials for the construction of houses and shelter. The production of oxygen, reduction of carbon-dioxide, maintaining the water cycle, and protecting soil are some important services. The loss of biodiversity and its habitat contribute to global climate changes. The loss of forest cover contributes to 'greenhouse effect'. Biodiversity loss is also causing major atmospheric changes, leading to an increase in global warming and changes in weather patterns. Biological diversity is also essential for preserving ecological processes, such as fixing nutrients, soil formation, circulation and cleansing of air and water, maintaining river flows throughout the year and local flood reduction. Biodiversity, apart from food**,** clothing and energy provides medicines. Moreover, it has great aesthetic, recreational and eco-tourism and religious significance. Biotechnologists use bio-rich areas for the purpose of teaching, research and for the development of better varieties of crops, for use in farming and plantation and to develop better livestock.

Biodiversity has great ethical and moral values. All the religious and nonreligious believe that all forms of life have the right to exist on earth. In each religion, some plants, animals, amphibians, reptiles and birds are considered as holy and important and to kill or harm such specie is a sin or crime. E.g. in Islam the oil of olive has a great value, so protection of such trees have some virtues, hunting of innocent sparrows and pigeons are not allowed without a serious cause.

Biodiversity has the following five aspects:

1. The distribution of different kinds of ecosystems, which comprise communities of plant, animals and microorganisms and the surrounding environment which are valuable not only for species they contain, but also in their own right.

2. The total number of species in a region or area.

3. The number of endemic species in a region or area.

4. The genetic diversity of an individual species.

5. The sub-populations of an individual species which embrace genetic diversity.

In recent years, especially after the concern of global warming and greenhouse gases, the environmentalists and biodiversity experts are focusing their efforts on biodiversity conservation and management, habitat protection, hotspots preservation. They also working for the reduction of environmental pollution and threatened species conservation.

HOTSPOTS OF BIODIVERSITY

The hotspots are the geographic areas which possess the highest endemic species. At the global level, these are the areas of high priority of conservation, if these areas lose their species, they can never be replaced.

How to recognize the hotspots?

- Hotspots can be recognized by the richness of the endemic species.
- It is the primary criterion.
- It should have a significant percentage of specialized species.
- It should be under threat.
- It should contain important gene pools of plants of potentially useful plants.

Area of hotspot: Hotspots covering less than 2% of the world's land are found to contain 50,000 endemic species. According to Myers et. al (2000) "an area is designated as a hotspot when it contains at least 0.5% of the endemic plant species." About 40% of terrestrial plants and 25% of vertebrate species are endemic and are found in hotspots.

BIODIVERSITY ESTIMATION OF THE WORLD

The total number of species on the Earth is still not known fully. According to one estimate that the number may vary from 10 to 100 million. These species are products of about 4 billion years but of which only about 1.5 million species are found and given specific scientific names. The variety and richness of plant and animal species may be examined at local, regional or global level. Only one third (1/3) of the global plants are identified. In tropical forest areas more than 1,50,000 flowering plant species are identified. about 50 to 80% global biodiversity lies in rainforests. Compared to forest and other resources, the maximum number of species are available in marine areas.

Biodiversity is currently facing many threats, one of the most important is habitat loss. Factors which influence the habitat loss are the Pollution, Population growth, Over-consumption or unsustainable use, Climate change, Illegal trade and developmental activities. Thus, both plant and animal species are under threat of extinction due to modification, degradation and loss of their habitats, causes by various developmental projects like industries, urban housing complexes, rail, road, and other communication networks, over exploitation, introduction of exotic species, pollution and global warming. Tropical deforestation alone reduces the biodiversity by 0.5% every year.

ENDANGERED SPECIES OF PAKISTAN

Endangered is a specie which is going to be extinct in near future and is known as endangered species. In other words, a species is said to be endangered which is under threat. The red data book was published by International Union for Conservation of Nature and Natural Resources (IUCN) which contains the details of endangered species of plants and animals.

By the national report on biodiversity submitted in 2009, there are total number of 195 mammal species (with 6 endemic species), 668 bird species, 177 reptile species, 22 amphibian species, 198 freshwater fish species, over 500 invertebrate species, and 5700 flowering plant species. Pakistan is home to many endangered species due to habitat loss, hunting, pollution, and climate change. According to the official forth national report on the biodiversity of Pakistan, out of the above total animals' species, there are about 25 bird's species, 20 mammal species, 13 reptile species, 5 fish types and 8 marine mollusks making a total of almost 70 endangered species. Here are some examples:

1. Snow leopard (Panthera uncia): Found in the mountain ranges of northern Pakistan, this majestic cat is threatened by habitat loss and human-wildlife conflict.

2. Asiatic black bear (Ursus thibetanus): Native to Pakistan's forests, this bear is threatened by habitat loss and poaching for its body parts.

3. Indus river dolphin (Platanista minor): The Indus River dolphin is one of the world's rarest mammals that is critically endangered with an estimate of 1000 living in the wild as reported by IUCN. Found only in the Indus River, this dolphin is threatened by pollution, habitat loss, and entanglement in fishing nets.

4. Hawksbill sea turtle (Eretmochelys imbricata): Pakistan's coastal waters are a nesting site for this turtle, which is threatened by pollution, entanglement in fishing gear, and egg collection.

5. Markhor (Capra falconeri): The national animal of Pakistan, this majestic goat is threatened by habitat loss, poaching, and competition with domestic livestock.

6. Urial (Ovis orientalis): A wild sheep species found in Pakistan's mountain ranges, it's threatened by habitat loss, poaching, and competition with domestic livestock.

7. Sindh ibex (Capra aegagrus): Found in southern Pakistan, this goat is threatened by habitat loss, poaching, and competition with domestic livestock.

8. White-backed vulture (Gyps bengalensis): Once common in Pakistan, this vulture is threatened by poisoning from carcasses of animals treated with diclofenac.

9. Blanford's fox (Vulpes cana): A small fox found in Pakistan's deserts, it's threatened by habitat loss, poaching, and competition with domestic dogs.

10. Pangolin (Manis crass Caudata): Found in Pakistan's forests, this unique mammal is threatened by poaching for its scales and meat.

11. Marco Polo Sheep (Ovis amoon polii)

Known for its large, corkscrew-like horns, the population of this wild sheep has declined due to overgrazing and hunting.

12. Red-headed Vulture (Sarcogyps calvus)

Various vulture species, including the red-headed vulture, have seen population decrease, putting them at risk of extinction.

Conservation efforts are underway to protect these and other endangered species in Pakistan, including habitat protection, research, and community engagement.

Biodiversity conservation

To conserve the biodiversity of a specific ecosystem, we must conserve the ecological niches of a particular organism. Niche is the unique functional role or place of species in an ecosystem. It is the way an organism obtains the physical, chemical, and biological factors it needs to survive. An individual species must satisfy several aspects in its niche. For example, the rabbits occur throughout Pakistan in habitats of desert and rangelands. Their trophic niche are wild grasses, plant leaves and fruits throughout the year. They are living in protected caves and thorny shrubs. They also breed in their habitat, especially on elevated slopes.

Based on the above example an ecological niche consists of: Habitat niche, Food niche, Reproductive niche, Physical and chemical niche, Geo-ecological niche. Ecological niches contain several factors to be favorable in that ecosystem to conserve the flora and fauna of that ecosystem.

IUCN SPECIES CATEGORIZATION FOR CONSERVATION

The International Union for Conservation of Nature (IUCN) has published their Red Data Book which categorized the species for conservation to be achieved worldwide as follows:

(i) Extinct Species

These are the species which are not found after exhaustive survey by all world species related organizations like WWF (worldwide fund for nature and natural resources) and IUCN (international union for conservation of nature and natural resources) and search of known or likely areas, where they occur. A species may be extinct from a local area, region, country, continent or the entire world. In other words, a species is extinct when there is no reasonable doubt that the last individual has died. A species is presumed as extinct, when exhaustive survey has failed to record an individual species. Examples of such species are the dinosaurs, wooly Mammoth, Asian Cheetah, Dodo birds, Pink Head Duck etc. The most recent functionally extinct but not fully extinct species of 2025 is northern white rhinoceros.

(ii)Normal species

Species whose population levels are normal for their survival, such as cattle, goats, sheep, rodents, mango, babul (Acacia), banyan, teak, pines etc.

(iii)Rare species

Rare Species are those species whose population is small, and the location is confined to limited areas. The rare species, in the time to come may become vulnerable and finally may be endangered. These species need to be provided with special care and attention in conservation programs.

(iv) Critically endangered (CR)

A species is considered as critically endangered, when the best available evidence fulfills the following:

i. Reduction in population (more than 90% over the last 10 years)
ii. Population size (number less than 50 mature)
iii. Quantitative analysis showing the probability of extinction in the wild (at least 50 percent within the last ten (10) years.)

(V) endangered (en)

A species is endangered when the best available evidence indicates that it meets any of the following criteria.

(i) Reduction in population size (70 per cent over the last 20 years)

(ii) Population size (estimated to be fewer than 250 mature individuals in the wild)

(iii) Quantitative analysis showing the probability of extinction in the wild (at least 20 percent within the last 20 years.)

(VI) Vulnerable (vu)

A species is vulnerable when the best available evidence indicates that it meets any of the criteria:

i. Reduction in population (more than 50 percent over the last 10 years)
ii. Population size is estimated to be fewer than 10,000 mature individuals.
iii. The probability of extinction in the wild is at least 10 per cent within the last 100 years.

(vii) Near threatened (nt)

A species is near threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered or Vulnerable now, but close to qualifying for or is likely to qualify, for a threatened category soon.

(viii) Least concern (lc)

A species is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant species are included in this category.

(ix)Data Deficient (DD)

A species is data deficient when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status. Data Deficient is therefore not a category of threat.

(x)Not evaluated (ne)

A species is not evaluated when it has not yet been evaluated against the given criteria.

STRATEGIES FOR BIODIVERSITY CONSERVATION

The term biodiversity conservation is associated with the sustainable utilization of natural resources to ensure sustainable development. Biodiversity conservation is required for ecological, biological, scientific, economic, cultural, and ethical necessities. The main objectives of biodiversity conservation are the protection, preservation, management and restoration of natural resources, especially fauna and flora. Biodiversity conservation is essential for the survival of mankind. The experts of ecology and environment have formulated a World Conservation Strategy for a judicious and un-exploitative use of biodiversity and the sustenance of life on the Earth's surface.

The key strategies for the conservation of biodiversity as designed by ecologists may be summarized as below:

1) The natural habitat of wildlife must be reserved to provide an unexploited environment for the preservation of all species of old and new flora, fauna and microbes.

(2) The fundamental physical parameters of soil, water, air and energy must be conserved through its proper management and most favorable use.

(3) As far as possible, the species of fauna and flora should be protected in their natural environment or at most in the anthropogenic conducive environment in zoological parks and botanical gardens.

(4) Protection and preservation of critical habitats and unique ecosystems.

(5) While all species of plants and animals should be protected, special monitoring should be done to conserve the threatened and vulnerable species.

(6) Protected areas should be demarcated where the natural habitats of wild relatives of useful plants and animals could be preserved.

(7) The critical habitats, such as nesting sites, feeding areas, and breeding grounds of wild animals need special attention.

(8) The ecosystem rather than a single species needs to be preserved.

(9) Over-exploitation of the various ecosystems should not be done.

(10) International trade in endangered species should be treated by regulations; exploitation or overuse should be banned or treated by finalities.

(11) Regulations of international trade in wildlife. Bilateral and multilateral agreements need to be reached to regulate the production and preservation of natural habitats of migratory animals and birds.

(12) Pollution should be reduced in such quantity and of such nature in which wildlife can survive.

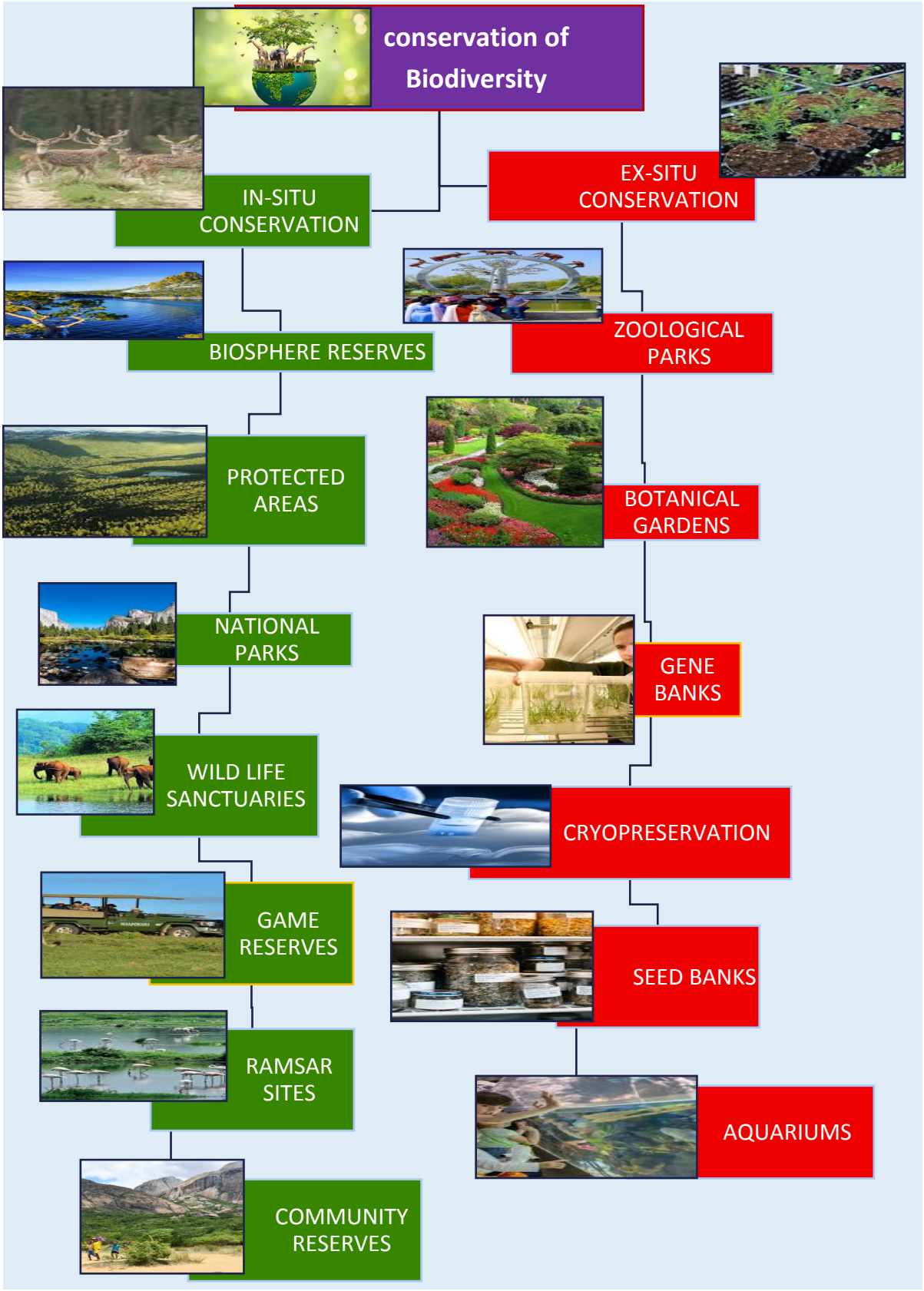
(13) Biosphere reserves, national parks, sanctuaries, zoological parks, etc. should be set up in all countries to protect the species of plants and animals.

(14) Hunting of threatened species should be completely banned, and in case of other species, it should be regulated through grant of licenses.

(15) The government must initiate an environmental awareness program at the national, regional and local levels. Sooner the above steps taken, the better for the conservation of biodiversity. There are two types of biodiversity conservation on the bases of location as follows:

In-situ and Ex-situ conservation

Experts of ecology and environment have suggested the strategy of in-situ and ex-situ biodiversity conservation. A brief description of these strategies has been given in the following:


conservation of Biodiversity
IN-SITU CONSERVATION
EX-SITU CONSERVATION
BIOSPHERE RESERVES
ZOOLOGICAL PARKS
PROTECTED AREAS
BOTANICAL GARDENS
NATIONAL PARKS
GENE BANKS
WILD LIFE SANCTUARIES
CRYOPRESERVATION
GAME RESERVES
SEED BANKS
RAMSAR SITES
AQUARIUMS
COMMUNITY RESERVES

EX-SITU CONSERVATION

In case the natural habitat is degraded substantially, numerous species are in the category of endangered species and in-situ conservation is not possible. In such cases, conservation needs to be done away from the natural habitat and should be under total human supervision in places such as zoological parks (zoos), botanical gardens, seed and gene banks, aquariums and cryopreservation. The main functions of such rehabilitation centers are as under:

1) Identification of the species to be conserved. The species which are at maximum risk of extinction are generally chosen for conservation.

(ii) To capture some individuals of the concerned critically endangered species of animals from their natural habitat and keep them the same as captives at these centers.

(iii) To study thoroughly feeding, breeding and other habits as well as patterns of their pathology (nature of diseases).

(iv) To provide all facilities for captive breeding of all such animals as well as for their healthy multiplication.

(v) Releasing young ones of these animals into the natural habitat after they have attained the safe age for the purpose.

(vi) Use of artificial insemination in genetic engineering as embryo transfer and cryo-preservation of gametes embryos to maintain the genetic diversity in ex-situ conservation.

(vii) Creation of zoological parks, botanical gardens, seed banks, aquariums and rehabilitation centers.

IN-SITU CONSERVATION

In in-situ biodiversity conservation, the natural habitats of different species of plants and animals are protected. The establishment of biosphere reserves, national parks and wildlife sanctuaries are some of the examples of in-situ conservation. In this type of biodiversity conservation, not only the endangered species and vulnerable species can be benefitted but also the constituents present in the ecosystem are protected. It is a cheap and natural way of conservation. The species are allowed to grow in their natural habitat. When these species grow in their natural habitat, they can face the fluctuations of weather, thereby developing into better adapted forms. For this reason, the wild species are sturdier and more resistant to the prevailing environmental conditions than the domesticated and hybrid species. The main advantage of in-situ conservation is that it requires a large area for the complete protection and conservation of biodiversity. This implies the restriction of human activity and a greater overlap or interaction of wildlife with residents near a reserved area. At present, there are more than 7000 protected areas, parks, sanctuaries and natural reserves in the world. It has been stressed that species cannot be protected individually as they are interdependent on each other to form a food chain and therefore, the whole ecosystem is to be protected. With the passage of time, new biosphere reserves and national parks are being delineated for the in-situ conservation of biodiversity.

The Blue Book of IUCN gives information about an encouraging new instrument for restoration and conservation of different species of plants and animals. According to IUCN data from 2020-2023, Pakistan has a total of 398 notified protected areas, which include 31 national parks, 92 wildlife sanctuaries, 97 game reserves, 160 community reserves, along with 19 Ramsar sites.

BIOSPHERE RESERVES

These are created by UNESCO in 1971 for the conservation of all areas, landscapes, their flora and fauna and all other cultural and heritage sites. These are international designations. The man objectives of biosphere reserves are to provide research, training facilities and protect natural environments. Human interaction is prohibited in the biosphere zone. Only research, education and training facilities are provided.

PROTECTED AREAS

Unlike biosphere reserves, protected areas are created by the state government or by central government. This may be a part of biosphere reserve. These are identified and demarcated by Pakistan wildlife and other attached departments. Grazing and limited hunting are allowed after the permission of the competent authority. Research, education and training facilities are not available. The examples of protected areas are national parks, wildlife sanctuaries and tiger reserves.

NATIONAL PARKS

National parks are declared in areas that are considered to have adequate ecological, geomorphological, cultural and natural significance. A national park is a relatively large area of one or several ecosystems that are not being materially altered by human exploitation and occupation. Here, plant and animal species, geomorphic sites and habitats are reserved for education and research.

National Parks enjoy greater degree of protection than sanctuaries. Grazing livestock is prohibited. National Parks are not focused on a particular species. They are created by the provincial government and in some cases by the federal government.

NATIONAL PARKS IN PAKISTAN

Hingol national park is the biggest national park of Pakistan in Balochistan province, covers an area of 6100 square kilometers, established in 1988.it consists of 35 species of mammals, 65 species of amphibians and reptiles, and 185 species of birds.

Kirthar national park is the second largest national park in Pakistan after Hingol national park locating in district jamshroo, Sindh. The fauna comprises Indian leopards, striped hyenas, Indian wolves, ratels, urials, chinkara gazelles and rare Sindh wild goats. Black buck antelopes and reintroduced them into the park through a project. Most large predators were killed before wildlife monitoring and conservation. Twenty-six (26) species of mammals are present.

Hazarganji chiltan national park is a national park in Mustung district of western Baluchistan province of Pakistan. The park was established in 1980 to provide habitat to the

rare Chiltan ibexes found in the area. It covers an area of 325000 acre of land located close to the chiltan mountain in outskirt.

Ayubia national park is a national park established before Pakistan creation for the purpose of the protection of different flora and fauna of Khyber Pakhtunkhwa, Pakistan. It is homeland of ibexes, wolves, snow leopards, white and brown bears, foxes, rabbits, marmots and many wild animals.

The bird's species are hawks, eagles and falcons. White pheasants, partridges, hoopoes, larks, sparrows, quails, doves, swallow starlings, crows and vultures.

Central Karakoram national park is also called Deosai national park locating in Skardu district of Gilgit-Baltistan. It encompasses some of the world's highest peaks and glaciers. This park protects the survival of the "Himalayan brown bear" and its habitat. The average elevation of these plateaus from sea level is 4,114 meters and considered as the second highest plateaus in the world.

Gumot national park is the high-altitude national park locating in Neelum valley north-eastern Pakistan. Conservation efforts in the park are funded by Global Environment Facility (GEF) and implemented by the Himalayan wildlife foundation. The park was established for the protection of threatened brown bear and musk deer.

Khunjerab national park is a national park in Pakistan adjacent to Taxkorgan natural reserve in China. It is established to protect Marco polo sheep, include bahral, snow leopard, Himalayan ibex, Indian wild Ass and brown bear.

Lal suhanra national park is a USESCO declared biosphere reserve and one of the South Asia largest national parks in Pakistan of district Bahawalpur. It is important for its different landscapes i.e. desert, forest and wetland ecosystems.

Main purpose of this park is to protect the wildlife of Chilostan desert. 302 species of plants, 119 species of birds, 27 species of reptiles, 3 of amphibians, 23 species of freshwater fish are found in it.

Machiara national park situated in Kashmir, district Muzaffarabad. The park is the habitat of broadleaves evergreen forest and deciduous broad-leaved woodlands and forms a part of western Himalayan broadleaf forest region.

Margala hills national park is a national park locating in Pakistan's capital. The park is rich in biodiversity, especially rich in Sino Himalayan fauna, most notably gray goral, barking deer, and leopard. The park is home to around 600 plant species, 250 bird's verities, 38 mammals and 13 species of reptiles.

Saiful Muluk national park is in Kaghan valley district Mansehra. It is the habitat of alpine forests.

WILDLIFE SANCTUARIES

They generally have one ecosystem. Wildlife Sanctuaries may be created for a particular species. Human interactions are allowed up to some extent in sanctuaries. Grazing of livestock and limited hunting of birds is allowed in sanctuaries after taking permission from the competent authority. The Sanctuaries are created by the State Governments. The example of wildlife sanctuaries in Pakistan are Baltistan, Astore, Chlolistan, Bajwat, Chashma and Taunsa barrage Dolphin sanctuary.

Baltistan wildlife sanctuary is famous for the conservation of threatened species, among them are snow leopard, brown bear, Lynx, Tibetan wolf, Tibetan sand fox, markhor, bharal and Siberian Ibex.

Bajwat wildlife sanctuary in Sialkot district provides protection for waterfowl, as well as a variety of mammals including Hog deer and Nilgai. Scientists have recorded 110 species on the site.

Cholistan wildlife sanctuary southern Punjab protect many creatures as desert wolf(rare), native Indian fox, red fox, jackal, little Indian mongoose, native Indian leave cat, forest cat, caracal cat, chinkara Gazelle, little Indian civet, black buck, nilgai antelope, houbara bustard, peregrine falcon, saker falcon, black supported vulture, native Indian cobra, observe reptile, saw scaly viper and russel viper.

Mahal kohistan wildlife sanctuary

Locating in the south of kirthar national park. Common wildlife includes fox, jackal, jungle cat, chinkara Gazelle, Urial, Monitor lizard and Indian cobra.

COMMUNITY RESERVES

“Community reserves” as a concept refers to protected or semi-protected areas where local communities play a central role in managing natural resources, wildlife habitat, and biodiversity. In Pakistan, there are several related categories, that embody parts of this concept. Below is a detailed overview of what community reserves are? how Pakistan uses related frameworks, legal basis, examples, benefits, challenges, and suggestions. A “community reserve” generally means:

i. Land under community control or ownership, or private lands, which the community agrees to manage for conservation of biodiversity, wildlife and habitat.
ii. The community participates in management decisions, sustainable use of resources, and balancing conservation with livelihood.
iii. Often, there is legal recognition or notification by government, giving protection status, rules/regulations for use, and possibly support from public or NGO institutions.

Some examples in Pakistan where communities are involved, or ownership is in community or landowner hands:

1. **Mandoor and Gujar Banr Community Game Reserves** (KP)

   These areas were notified under the "KP Community Game Reserves Rules 2019." They are to be managed by the owners of the land, with rules defined by the provincial wildlife department.

2. **Nature Reserves in Chakwal, Punjab**

   Three nature reserves spanning ~18,000 acres in Parera, Ara and Dil Jabba areas. These reserves have been notified under the Prime Minister's Protected Areas Initiative. Notably, forest guards were hired from the local community.

3. **Shahi Nagar Community Game Reserve (Buner, KP)**

   Recently notified. Small in area about 161 hectares.

GAME RESERVES

Game reserves are large areas of land where wild animals are hunted in a controlled way for sports. Many game reserves are in Africa, but they can be found in other parts of the world as well. The purpose of game reserve is to provide a controlled environment for wild animals, while also promoting conservation and protection of ecosystems. There are different types of game reserves, including those that are open to the public and those that are private. Game reserves offer various activities, such as sightseeing safaris, hunting and wildlife viewing.

Game reserves play an important role in conservation efforts, as they provide a protected area for wildlife animals to live and thrive. The conserved game reserves can generate income for local communities through tourism and hunting activities.

Game reserves examples:

Kala chitta: a game reserve in Pakistan that is home to a variety of wildlife, including birds and animals.

African lion safari: a drive-through game reserve in Canada that features animals from around the world.

Nairobi sanctuary: a game reserve in Africa that is part of African lion safari drive-through park.

RAMSAR SITES:

Ramsar Sites are wetlands of international importance designated under the Ramsar Convention (1971), an international treaty signed in Ramsar, Iran. The purpose of Ramsar sites is to conserve wetlands and ensure their wise use for biodiversity, water regulation, flood control, and livelihoods. Each Ramsar site is recognized for its ecological, hydrological, cultural, and socio-economic values. Pakistan became a party to the Ramsar

Convention in 1976. Currently, Pakistan has 19 Ramsar sites covering about 1.34 million hectares. These wetlands are crucial for Migratory birds.

Ramsar sites, also called wetlands, are very important because they provide Biodiversity hotspots (fish, reptiles, plants, mammals). They are Habitat for endangered species like Indus River Dolphin, Siberian cranes, marine turtles. Over 1 million birds use these wetlands annually via the Indus Flyway. Local livelihoods such as fisheries, agriculture, and tourism provide income to local communities. Ecosystem services like flood control, groundwater recharge, and climate regulation. Wetlands act as carbon sinks, regulate floods, and recharge groundwater.

Keenjhar Lake (Karli Lake), Haleji Lake, Indus Dolphin Reserve, Thanedar Wala, Chashma Barrage, Taunsa Barrage, Uchhali complex, Jiwani coastal wetland, Ormara turtle beaches and Astola island are some examples of some demarcated Ramsar sites (wetland) in Pakistan.

HABITAT RESTORATION (ECOLOGICAL RESTORATION)

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed to restore their natural structure, function, and biodiversity. Ecological restoration aims to recreate, initiate, or accelerate the recovery of an ecosystem that has been disturbed. Disturbances are environmental changes that alter ecosystem structure and function. Common disturbances include logging, damming rivers, intense grazing, hurricanes, floods, and fires.

Ecological restoration has many goals such as habitat reconstruction, revegetation, reintroduction of native species, reestablishing natural processes such as nutrient cycling, water flow, and soil formation, improve ecosystem services and Enhance biodiversity. This uses the methods of ecosystem engineering using either natural or artificial means to promote ecosystem restoration.

Ecological restoration can improve ecosystem health, can restore natural resources and biodiversity, can sequester carbon and other greenhouse gases to reduce climate change. Restoration can improve human well-being by providing recreational opportunities, improving air and water quality, and supporting local economies. While we can successfully restore biodiversity, structure, and function to a degraded ecosystem. Ecological restoration is not a substitute for conservation, nor should the promise of restoration be used to justify destruction or unsustainable use. Restoration may not succeed in re-establishing the full assemblage of native species or the full extent of the original ecosystem's structure and function.

According to the UN COP16 (convention on biodiversity (CBD) held in two parts: first in Colombia from 0ctober21 to November 1,2024 and second in Rome, Italy, in February 2025), the United Nations has named 2021-2030 the Decade on Ecosystem Restoration. The UN decade of ecological restoration led by the United Nations Environment Programme, the Food and Agriculture Organization of the United Nations and its partners, covers

terrestrial as well as coastal and marine ecosystems. The COP16 monitoring framework sets a goal for at least 30% of degraded freshwater, marine, and land ecosystems to be under effective restoration by 2030. As a global call to action, it will draw together political support, scientific research and financial muscle to massively scale up restoration.

BIODIVERSITY CONSERVATION & RESTORATION (CASE STUDIES OF PAKISTAN)

1) **Indus River Dolphin — rescue, monitoring & habitat protection**

Long-running conservation led by WWF-Pakistan with Sindh/Punjab wildlife authorities, local fishers and communities. Activities include large population surveys, radio-tag monitoring, a dolphin-rescue network for animals stranded in irrigation canals, public awareness and promotion of dolphin-friendly fishing practices.
The outcomes were Population estimates improved dramatically since monitoring began; rescue Programme has saved many stranded dolphins and informed management. Surveys show recovery trends with WWF estimates ~1,800–2,000 individuals in recent years.

2) **Mangrove restoration — Indus Delta / Thatta (blue carbon & coastal protection)**

Large mangrove restoration and protection efforts involving Sindh Forest Department, WWF, UNEP and other partners; many projects are integrated into Pakistan's national tree-planting and restoration drives and blue-carbon initiatives e.g., Delta Blue Carbon.
Activities: large-scale planting of native mangrove species, protection from clearance, community-based nurseries and livelihood links.
National studies report substantial increases in mapped mangrove area over recent decades; restoration provides coastal protection, fisheries benefits and measurable carbon sequestration ("blue carbon").

3) **Ten Billion Tree Tsunami (afforestation & forest restoration; TBTT) Khyber Pakhtunkhwa & nationwide scaling**

Government-led large afforestation and restoration initiative building on KP's earlier Billion Trees Programme, implemented with provincial forest departments, NGOs and community nurseries. Focused on restoring degraded hills, riverbanks and forest lands, plus private nurseries and employment.

Independent audits and reports show high survival rates in many planted sites (audits reported 75–85% survival in some evaluations) and local economic benefits via nursery jobs. Results vary by site; papers note increases in forest cover in KP and measurable carbon gains.

4) Snow leopard conservation

Multiple programs (Snow Leopard Trust, local NGOs, government agencies, community conservation programs) focused on population surveys, community incentives (pastoralist compensation, predator-proof corrals), ecotourism, and landscape connectivity in the Karakoram / Hindu Kush / Himalaya. Pakistan recently completed its first nationwide

snow-leopard count/assessment, providing a baseline for future action.
Better population estimates and strengthens community stewardship in key valleys; community incentives reduce retaliatory killing and support coexistence.

5) Juniper forest conservation — Ziarat & Zarghoon (Balochistan)

Conservation projects by collaboration of UNDP FAO, and provincial government efforts to conserve ancient Junipers forests (Ziarat, Zarghoon). Activities include protection against illegal cutting, scientific assessments of regeneration, fire management, community awareness and limited restoration trials.

Juniper forests are recognized for global significance (large, ancient stands). Studies highlight slow regeneration and threats (fuelwood collection, grazing, climate stress), leading to targeted conservation project proposals and management plans.

6) Wetland protection

Haleji and Keenjhar Lakes are Ramsar-listed wetlands with monitoring and restoration proposals involving federal and provincial agencies and academic assessments. Work includes inventorying birds and fauna, water-management proposals, and studies on pollution and inflow management.
Detailed inventories exist but long-term threats persist (reduced inflows, pollution, management gaps). Several studies propose reconnecting to Indus flows or improving water storage/quality to revive wetland function.

CHAPTER- 6 NATURAL RESOURCES MANAGEMENT

Materials found in nature that can be put to some use by human beings for their growth, development, comfort and other necessities are called natural resources.

TYPES OF NATURAL RESOURCES

All the natural resources can be divided into two categories-

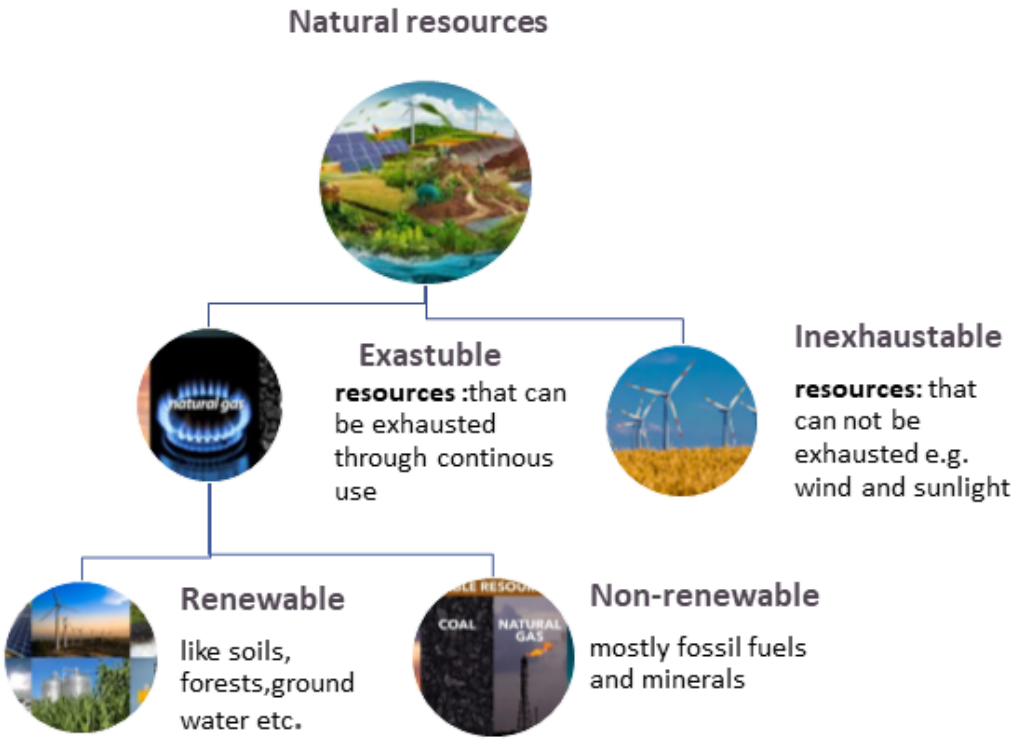
I. Exhaustible resources
II. Inexhaustible resources

Exhaustible natural resources are water, coal, forests, soil, petroleum, minerals, natural gas, fisheries, range lands, biodiversity, watershed etc. These are consumed through continuous use or misuse.

Exhaustible natural resources can be further divided into two categories-

b) Renewable natural resources
c) Non-renewable natural resources

Inexhaustible natural resources are those which cannot be exhausted through continuous use or misuse e.g., wind and tidal energy.



NONRENEWABLE RESOURCES OF PAKISTAN

Pakistan has many non-renewable resources. Pakistan is heavily dependent on Pashtun khawa and Balochistan provinces for its mineral deposits. In fact, Balochistan makes up

about 43% of Pakistan's landmass and has a geological belt with known world-class mineral deposits.

Fossil Fuels

Pakistan has significant fossil fuel resources, including coal, oil, and natural gas, which play a vital role in the country's energy supply. The Thar coal field in Sindh is one of the largest Lignite coal reserves in the world. Oil reserves are mainly found in Khyber Pakhtunkhwa, Punjab, and Balochistan, while natural gas is largely produced from the Sui gas field in Balochistan and other fields in Sindh. Despite these resources, Pakistan still faces energy shortages due to limited production and increasing demand, highlighting the need for improved exploration and a shift toward renewable energy sources.

Coal

Pakistan has significant coal reserves, particularly in the Balochistan province in duki, sinjavi, harnayi locations and in some part of Thar Desert, Sindh. Coalfield is estimated to have around 175 billion tons of coal.

Oil

Pakistan has limited oil reserves, with most of its oil being imported. Pakistan has limited oil reserves, some oil fields locating in the Potohar Plateau, Punjab. The country's oil reserves are estimated to be around 247 million barrels.

Natural Gas

Pakistan has significant natural gas reserves, with major fields in Sindh and Balochistan. Sui is the largest reservoir in Pakistan locating in Balochistan Dera Bugti, being operational from last sixty years. The reservoir was discovered in 1952. The country's natural gas reserves are estimated to be around 885 billion cubic meters.

Minerals

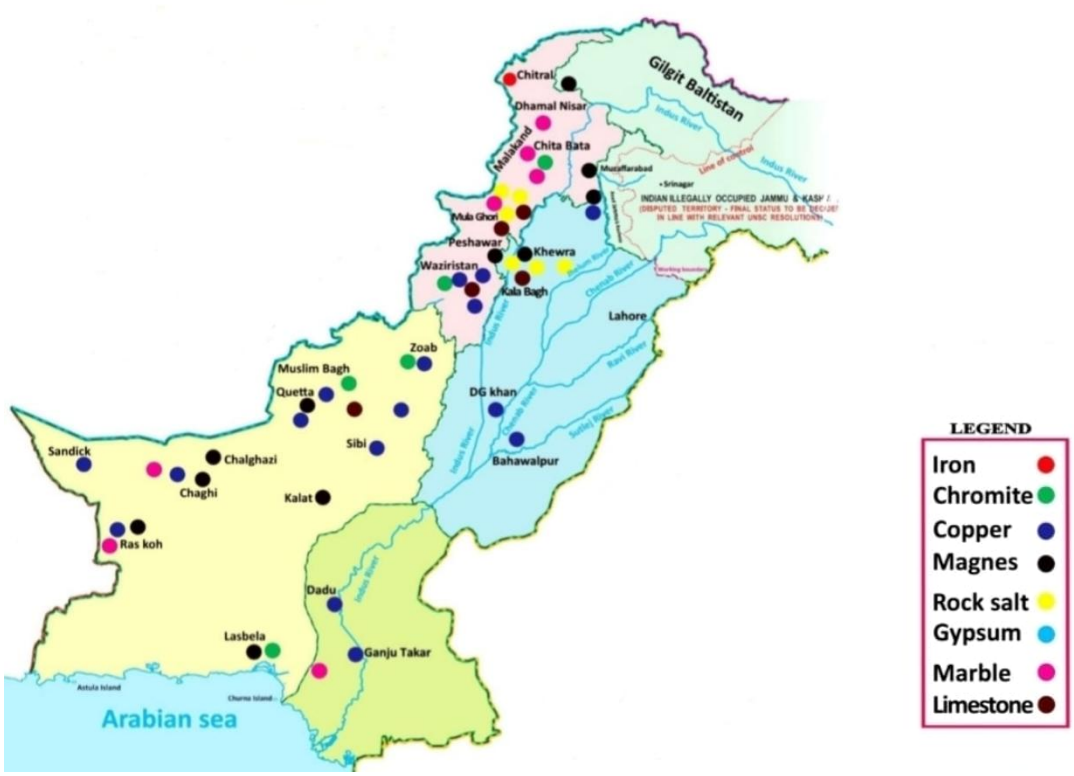
Chromite

Chromite is the chief ore of chromium (Cr_2O_3), used mainly in stainless steel, alloys, refractory materials, and chemicals. Pakistan possesses significant chromite resources. Pakistan’s chromite resources are concentrated mainly in Balochistan in districts: Muslim BAGH, Zhob, Khanozai (Pishin), Nasai (Killa Saifullah), Wadh (Khuzdar), Bela (Lasbela) with largest chromite deposits; mining since early 1900s, with additional deposits in Khyber Pakhtunkhwa and minor occurrences in Gilgit-Baltistan. Despite large reserves, industrial utilization remains low due to lack of processing facilities and modern mining practices.

Gold and Copper

Copper is one of Pakistan’s most valuable mineral resources, mainly found in the province of Balochistan. The country’s largest copper deposits occur in the Chagai District, which

forms part of the Tethyan Metallogenic Belt, a globally significant copper-gold zone. The two major deposits are Reko Diq and Saindak. Reko Diq is considered one of the world's largest undeveloped copper-gold deposits, estimated to contain about 5.9 billion tonnes of ore. The Saindak project, operated by Saindak Metals Limited, produces copper along with by-products of gold and silver. Other known deposits in Balochistan include Dashte-Kain, Nok Kundi, Koh-e-Sultan, and Ziarat. Smaller copper occurrences are also reported in Khyber Pakhtunkhwa (Dir, Chitral, Waziristan, and Kohistan) and Gilgit-Baltistan, though these are not yet developed on a large scale. Most of Pakistan's copper deposits are porphyry-type, associated with volcanic and intrusive rocks. Presently, copper production is limited to Saindak, yielding about 15,000 tons of refined copper annually, while Reko Diq is under development. The main challenges include the lack of modern mining technology, refining facilities, and infrastructure. However, with the full operation of Reko Diq and investment in local processing industries, Pakistan has the potential to become a major producer and exporter of copper and gold in Asia.



Iron Ore

Pakistan has considerable iron ore resources, found in several regions across the country, with major deposits located in Balochistan, Punjab, and Khyber Pakhtunkhwa. The most important deposits occur at Kalabagh (Mianwali District, Punjab), Chiniot (near Faisalabad, Punjab), and Dilband (Mastung District, Balochistan). The Chiniot–Rajua Sadat deposit is one of the largest, containing an estimated 500 million tons of iron ore, discovered through joint exploration by the Geological Survey of Pakistan and international experts. The Dilband deposit supplies raw material to Pakistan Steel Mills in Karachi, while Kalabagh contains high-grade hematite and magnetite ores. Smaller occurrences of iron ore are also

reported from Kohat, Haripur, Hazara, and Chitral regions in Khyber Pakhtunkhwa, and Chagai in Balochistan. Most of these deposits are sedimentary or magmatic in origin, consisting mainly of hematite and magnetite minerals. Despite having sufficient reserves to meet domestic needs, Pakistan still imports iron and steel due to limited mining, processing, and smelting capacity. With better exploration, infrastructure, and steel-making facilities, these deposits could significantly reduce dependence on imports and strengthen Pakistan's industrial base.

Limestone

Limestone is one of the most abundant and widely distributed industrial minerals in Pakistan, used extensively in the cement, construction, and chemical industries. Major limestone deposits are found in Punjab, Sindh, Balochistan, and Khyber Pakhtunkhwa provinces. The Salt Range and Margalla Hills in Punjab contain extensive high-purity limestone, which forms the main raw material for numerous cement plants. In Sindh, large deposits occur in Thatta, Hyderabad, and Karachi divisions, while in Balochistan, the Sor Range, Harnai, and Loralai areas hold substantial reserves of good quality limestone. Khyber Pakhtunkhwa also hosts deposits in Nowshera, Kohat, and Malakand, supporting local cement industries. Geologically, the limestone belongs mainly to formations of the Jurassic and Eocene ages, such as the Samanasuk, Margalla Hill, and Kirthar formations. Pakistan's limestone resources are not only abundant but also of high chemical purity, making them suitable for cement, lime, and industrial applications. With proper management and modern quarrying, limestone can continue to play a vital role in Pakistan's construction and industrial development.

Rock salt

Pakistan is rich in rock salt resources, which are among the oldest and largest deposits in the world. The most famous deposit is the Khewra Salt Mine in the Salt Range of Punjab, located in Jhelum District, which is also the second largest salt mine globally. Other important salt deposits in the Salt Range include Warcha, Kalabagh, and Bahadur Khel. The Salt Range, extending across districts of Jhelum, Chakwal, and Mianwali, consists mainly of Precambrian rock salt interbedded with gypsum and dolomite. Additional salt deposits occur in Sindh at Jhimpir and Mauripur, and in Balochistan near Kohlu and Kalat. Pakistan's salt is primarily composed of sodium chloride (NaCl) and is known for its high purity and pink color, especially from Khewra, which is marketed worldwide as Himalayan Pink Salt. The annual production of rock salt is substantial, meeting domestic needs and supporting exports. With proper mining technology and value-added processing, Pakistan's salt industry holds strong potential for industrial, chemical, and export development.

Gypsum

Pakistan possesses vast reserves of gypsum, a soft sulfate mineral composed of calcium sulfate dehydrate ($CaSO_4 \cdot 2H_2O$), widely used in cement, fertilizer, plaster, and construction industries. Major gypsum deposits are found in Balochistan, Punjab, Sindh, and Khyber Pakhtunkhwa. The Suleiman and Kirthar mountain ranges of Balochistan contain extensive

high-quality gypsum deposits, particularly in Sibi, Dera Bugti, Loralai, and Kalat districts. In Punjab, significant reserves occur in the Salt Range, Dera Ghazi Khan, and Mianwali areas, often associated with limestone and marl formations. Sindh also hosts gypsum in Thatta and Karachi divisions, while in Khyber Pakhtunkhwa, deposits are located in Kohat, Karak, and Dera Ismail Khan. The estimated total reserves of gypsum in Pakistan are several hundred million tons, ensuring a steady supply for domestic industries. With efficient extraction and processing, gypsum can further contribute to cement manufacturing, soil conditioning, and export markets, supporting Pakistan's industrial and agricultural sectors.

Manganese

Manganese deposits in Pakistan are found mainly in Lasbela and Khuzdar districts of Balochistan, as well as in parts of Khyber Pakhtunkhwa and the Federally Administered Tribal Areas. The ore occurs mostly in association with sedimentary and metamorphic rocks. Although the reserves are moderate, manganese plays a vital role in the steel and alloy industries, where it is used as a hardening and deoxidizing agent. With proper exploration, mining, and processing, Pakistan's manganese resources could support domestic industrial needs and reduce reliance on imports. Following is some detail map of minerals of Pakistan.

The energy sector in Pakistan has a challenge to its economic development. The sector has made progress since 2013 in terms of power generation and reducing power crisis. But it is still facing challenges due to the high cost of fuel sources. The country is still dependent on imported energy products, insufficient natural gas supplies, mounting debt, and outdated transmission and distribution systems.

According to national electric power regulatory Authority's (NEPRA) 2022 annual report, Pakistan's total installed power generation capacity is 43,775 MW, of which 59% of energy comes from thermal (fossil fuels), 25% from hydro, 7% from renewable (wind, solar and biomass), and 9% from nuclear.

Pakistan is taking steps towards meeting its energy demands and reducing greenhouse gas emissions. The Government of Pakistan (GOP) is actively pursuing renewable energy investments on a large scale, as part of its clean energy goals in sustainable development agenda 2030. Pakistan has set a target to reduce its greenhouse gas emissions by 50% by 2030, and clean energy expansion will play a crucial role in achieving this objective.

HYDRO ENERGY:

Pakistan has a significant hydro energy potential, with most of its renewable energy coming from hydroelectricity. The country is harnessing to increase its hydro energy capacity to reduce its reliance on imported fossil fuels such as oil to mitigate energy shortages. The country aims to increase its hydro energy capacity to 60 % of its total installed capacity by 2030, with plans to add up to 10GW of new hydropower capacity.

Pakistan's hydro power sector has been growing significantly. As of September 2024, the country has an installed hydropower capacity of around 11,519 MW. which accounts for approximately 25% of its total installation capacity. The goal is part of Pakistan's strategy to transition towards cleaner and more sustainable energy sources. Some of the most important hydropower projects in Pakistan are Ghazi Baritha (1450 MW), Mangla Dam project (1070 MW), Korat (720 MW), chashma (184 MW) and warsak (242.96 MW).

SMALL/MINI/MICRO HYDROELECTRIC

As Pakistan is almost dependent on hydro power because of plenty of watersheds and rivers. Besides launching the Maga projects the country also developed small-mini-micro hydropower with a revised Renewable energy policy. The GOP considers small hydropower projects as a clean and inexpensive source of energy. Small hydropower projects are mainly located in remote areas of Pakistan particularly the North of the country. Recently, the GOP has identified new generation requirements by capacity, fuel technology, and utilizing indigenous resources for power generation by announcing the Indicative Generation Capacity Expansion Plan (IGCEP). This plan aims to add 13,000 MW of hydropower to the current 9000 MW capacity by 2030.

SOLAR ENERGY

Pakistan has been rapidly growing its solar power sector, with solar installations providing an estimated one-third of the country's entire generating capacity added in 2024 alone. As of 2024, the country has an installed solar power capacity of 780 MW.

The Quaid-e-Azam Solar Park in Bahawalpur, Punjab, is one of the largest solar power projects in Pakistan, with a total planned capacity of 1,000 MW. The project has already commissioned 400 MW and is expected to be expanded further.

Solar power entered Pakistan's energy mix in 2013 after the government introduced a set of support policies to foster renewable energy development. According to the Private Power & Infrastructure Board (PPIB) of the Ministry of Energy, seven solar projects of 530 MW are operational and supplying electricity to the national grid.

With the rising costs of electricity in Pakistan and an unreliable grid supply, more industries and commercial organizations are turning to captive solar solutions. There has been a strong surge in domestic installation of rooftop photovoltaic panels in larger cities. For projects under 1 MW, net metering regulations came into effect in September 2015. The current state of the energy sector is promising for growth in solar power in the future.

To further promote solar power, the Punjab government has launched the Chief Minister Punjab Free Solar Panel Scheme, which aims to provide up to 100,000 free solar systems to low-income households.

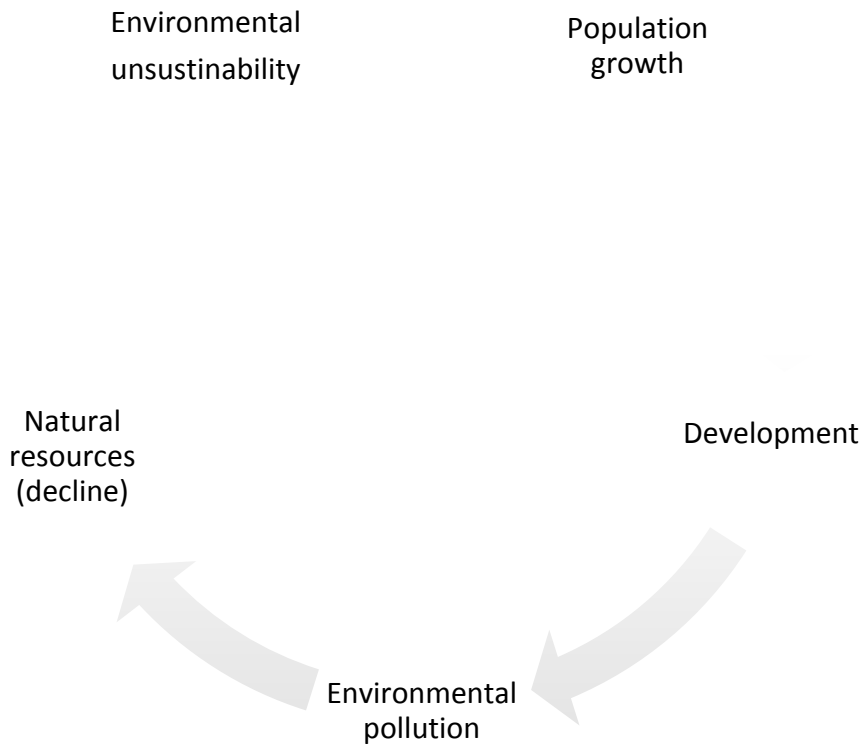
WIND ENERGY

Pakistan has considerable potential for using wind energy in the coastal belt of Sindh and Baluchistan (in southern Pakistan). The Government of Pakistan has developed a wind power energy corridor along the southern coastal regions of Sindh and Baluchistan. Wind data, provided by Pakistan's Meteorological Department, measures Pakistan's coastal belt at 60km (Gharo-Keti Bandar) and 180km long, with a projected potential of 50,000MW of electricity generation through wind turbines. Currently, 36 private wind projects are operating, producing approximately 1845MW. The Government of Pakistan renewable energy (RE) policy envisages generating 60 percent of the country's energy from renewable resources by 2030. The ambitious target provides several opportunities for the wind energy market in Pakistan.

GLOBAL ISSUE OF NATURAL RESOURCES

Before the free industrial period, the population was in balance with natural resources. In other words, the natural resources were flinty for living beings but currently the natural resources are limited and are not in balance with growing population. Some resources of the world are unequally distributed globally. Some parts of the world have a smaller population but using half of the resources. For example, the US and Great Britain have less than one third of the world population but use more than half of resources. The second global challenge is industrialization. The steps were taken to solve the problem of limited resources for growing population, but the huge industrialization created the pollution problem. These challenges altering the natural environment and creating burden on it.

According to the world experts that earth is experiencing four challenges: population growth, ecosystem and natural resources decline, global pollution and loss of biodiversity.



FOOTPRINTS (NATURAL RESOURCE DECLINE)

An ecological footprint measures the amount of biologically productive land and water needed to support a particular population or activity, including the resources consumed and waste produced. It's a sustainability indicator that helps us understand the environmental impact of our consumption and lifestyles. It helps determine if our current consumption patterns are sustainable by comparing the demand for Earth's resources with the planet's capacity to replenish them. Some scientists define the ecological footprint as “The measure of human demand on the Earth’s ecosystems”. It is a standardized measure of demand for natural capital that may be contrasted with the planet’s ecological capacity to regenerate and represent the amount of biologically productive land and sea area necessary to supply the resources a human population consumes, and to assimilate associated waste.

Currently, humanity’s total ecological footprint is estimated at 1.5. In other words, humanity uses ecological services 1.5 times as fast as the Earth can renew them. Today,

more than 80 percent of the world's population lives in countries that are running ecological deficits, using more resources than their ecosystems can regenerate.

The "carbon footprint" is the amount of carbon being emitted by an activity or organization. The carbon component of the ecological footprint converts the amount of carbon dioxide being released into the amount of productive land and sea area of carbon dioxide being released into the amount of productive land and sea area required to sequester it and tells the demand on the Earth those results from burning fossil fuels. The carbon footprint is 54% of the ecological footprint and its most rapidly growing component having increased 11fold since 1961. Every year Global Footprint Network (GFN) presents a report on ecological footprint which maps consumption and the requirement of natural resources to sustain it. Lifestyle adopted in developed countries is unsustainable and it will require five Earths to fulfil their lifestyle demands.

NATURAL RESOURCE MANAGEMENT (NRM) STRATEGIES

NRM involves a systematic approach to managing natural resources sustainably. The following affective strategies must be undertaken:

Assessment

Collection of data on the type, quantity, and quality of natural resources, this is called resource inventory**.** Then to evaluate the health and integrity of ecosystems, including biodiversity, water quality, and soil health. Then to Understand the relationships between natural resources, ecosystems, and human communities.

Planning

The steps to develop a management plan i.e Set clear goals, objectives, and strategies for sustainable resource management. The comprehensive management plan that outlines strategies, actions, and timelines for achieving the goals and objectives. The Establishment of clear goals and objectives for NRM, based on the assessment findings.

The use of GIS tools and techniques to analyze and visualize spatial data, including land use, land cover, and ecosystem services. Using different scenarios for planning to explore and develop strategies to address potential challenges and opportunities.

Stakeholders Engagement and public Participation

Engagement of local communities, indigenous peoples, governments, NGOs, and private sector entities. Foster cooperation and coordination among stakeholders must be under consideration. Involve stakeholders in decision-making processes to ensure that their concerns and interests are addressed.

Resource Monitoring and Evaluation

Establish monitoring systems. Track changes in natural resource conditions, ecosystem health, and human well-being. Establish indicators and monitoring protocols to track progress and adapt management strategies as needed. Assess the effectiveness of management strategies and identify areas for improvement. Based on monitoring and evaluation results, adapt management strategies to ensure sustainability.

Sustainable Resource Use and Conservation

Promote eco-friendly practices, such as sustainable agriculture, forestry, and fisheries management. Establish protected areas, restore degraded habitats, and control pollution. Encourage local communities to adopt sustainable livelihoods that minimize harm to natural resources.

Conflict Resolution and Governance

Define roles, responsibilities, and decision-making processes. Resolve conflicts between stakeholders, such as land-use disputes or resource allocation. Promote accountability, transparency, and integrity in natural resource management. Establish a governance structure that outlines roles, responsibilities, and decision-making processes.

Capacity Building

Enhance the skills and knowledge of stakeholders, including local communities and resource managers. Educate stakeholders about the importance of sustainable natural resource management. Provide training and education programs to the professional and Strengthen institutions responsible for NRM.

Research and Education

Encourage research, innovation, and technology transfer to improve natural resource management practices. Use remote sensing technologies to monitor natural resources. Apply data analytics to inform NRM decision-making. Promote the development and use of renewable technologies.

Economic Incentives

Provide financial incentives for landowners to conserve natural resources. Support sustainable livelihoods that reduce dependence on natural resources. Promote economic development that prioritizes environmental sustainability.

Some major resources and their management strategies can be discussed in the following

FISHERIES AS NATURAL RESOURCE

Fish is a vital source of food. Fisheries include fish, whales, seals, pearls, crustaceans (i.e. lobsters, crabs, prawns, and shrimps), mollusks (i.e. oysters, mussels, cockles, clams), sponges and seaweed. The marine resources are, however, an inexhaustible resource. In fact, fishing like mining is a ‘robber industry’. If a man catch fish at a rate faster than nature

can replace them, there will eventually be very few left. Overfishing and especially the wasteful killing of immature fish must be checked, not just by individual country, but "as fish know no national boundaries." on an international basis. The productivity of fish varies from latitude to latitude from ocean to ocean. The major determinants of fish products are as under:

(i) The depth of water (ii) the ocean currents, (iii) the temperature and salinity of the oceans, and (iv) the number of plankton or fish food present.

CONDITIONS FAVORABLE FOR FISHING GROUNDS

Fishing is done in all seas and oceans of the world. But most of the commercial grounds are in the temperate latitudes. Commercial fishing is little developed in the tropical waters. The major determinants of fishing grounds are as under.

1. Temperate Latitudes: In the high latitudes, there is an abundant supply of phytoplankton. The phytoplankton are tiny plant organisms, which form the food of zooplankton (microscopic animals), which in turns become the food of fish. The fish in turn are eaten by larger fish and sea mammals, i.e. seals and whales.

2. Cool Climate: The sea water temperature less than 20°C is more conducive for the fast multiplication of fish. In fact, the largest fishing grounds of the world are found in the regions, where the oceanic surface temperature is between 10°C to 15°C.

3. Availability of Cheap Labor: For the catching, cleaning, cutting, salting, pickling, drying or canning and marketing of fish, cheap labor is imperative.

4. Availability of Market: Big markets are also required for the development of fish industry.

MAJOR FISHING GROUNDS

The significant fishing grounds of commercial fishing of the world are:

1. Northeast Atlantic Ocean: This fishing region extends from Iceland to the Mediterranean shores. In these regions, fisheries are highly organized by the European countries.

2. North Sea: Herring is the dominant species in the North Sea. More than millions of tons of fish are caught from this region annually.

3. Northwest Atlantic: This region stretches from Newfound land to New England (USA) coastal seas of the Northwest Atlantic. The Grand Bank, George's Bank, Sable Bank, are the main fishing areas of this region. The merger of Gulf Stream and the Labrador Currents create ideal conditions for the fast multiplication of fish in this region.

4. The Northeast Pacific: It covers the continental shelf from Alaska to California. The main fish in this region is salmon.

5. The Northwest Pacific: This fishing ground covers from Bering Strait to the East China Sea. Salmon is the main fish of this region.

6. Other Fishing Grounds: Fishing is also done in the India Ocean, coasts of Chile and Peru and the countries of Southeast Asia.

FISH SPECIES ON THE BASES OF WATER HABITAT

There are two main types of fish, namely Salt-water fish which spend their entire lives in the oceans and seas, and the freshwater fish which are found in inland streams, rivers and lakes. There are some anadromous fish, chiefly the salmon, which are spawned in the inland rivers, but spend most of their lives in the seas and only return to rivers to spawn and die.

Saltwater Fish

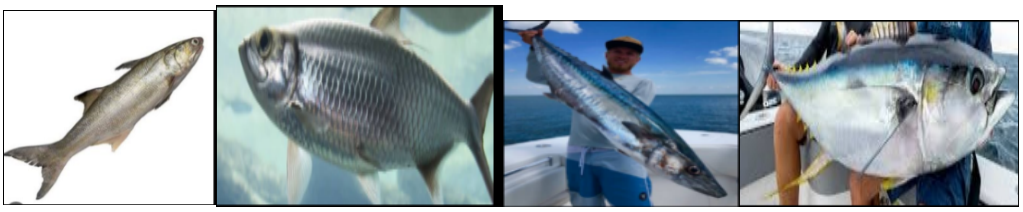
There are thousands of species of saltwater fish in the seas and oceans, but the most numerous is the herring. The herring is found in large shoals which may be 15 km in length and 6 km in width and comprises as many as about 700,000 herrings. They swim between 15 and 30 meters below the surface and are caught by drift, usually at night, because they swim deeper during the day. The mackerel is another important pelagic fish about 60 cm in length. It is tasty but perishable and is best consumed fresh. It is mainly found in the Mediterranean Sea, North Sea, Baltic Sea, and the Yellow Sea. They are caught by seine nets or purse seine. Other pelagic fish caught in temperate waters are sardine, pilchards, brisling, anchovies, cod and menhaden. These species are usually smaller in size. These fish are caught by trawl nets. Other white fish include the flatfish, brill, catfish, dogfish, dab, hake, haddock, halibut, sole, and tuna.

Fresh Water Fish

Freshwater fish are less important from the commercial point of view. They rarely swim in large shoals, and the fishing areas are rather restricted. The main fish of fresh water are trout, perch, pike, salmon and carp in rivers and lakes.

Anadromous Fish

Salmon is the most important fish in this category. It is extensively fished in North America, particularly from Alaska to Oregon on the Pacific coast. There are five major species of salmon: Chinook, humpback, sockeye, silver and chum. The young salmon live in the sea but after 2 to 5 years, they return to the stream where they were born to lay their own eggs or die. Following are the world's most famous species



Salmon herring (silver fish) king mackerel giant tuna

THREATS TO FISHERIES

1. Overfishing

Overfishing can lead to the depletion of fish stocks, making it difficult for fisheries to sustain themselves. This practice can also damage marine ecosystems, leading to long-term consequences for the health of the ocean.

2. Habitat Destruction

Coral reefs are essential habitats for many fish species, but they are being damaged by human activities such as coastal development and pollution. Mangroves and seagrasses are also important habitats for fish, but they are being lost due to deforestation and coastal development.

3. Pollution

Chemical pollutants such as pesticides and industrial chemicals can harm fish and other marine life. Plastic pollution is also a major threat to fisheries in the modern world as plastic debris can harm fish and other marine life.

4. Ocean acidification

Increased pollution, mostly carbon dioxide levels in water lead to respiratory distress in fish and other marine organisms. This can affect the growth and development of fish leading to size, skeletal development and impaired swimming ability. This can reduce reproduction and increased mortality. It can also affect fish migration and disturbance in food web.

5. Climate Change

The effects that cause the change of ocean temperature and chemistry, which can affect the distribution and abundance of fish. Climate change can also lead to increased disease and parasites in fish populations.

6. Invasive Species

Invasive species can outcompete native fish for food and habitat, leading to declines in native fish populations.

7. Coastal Development

Coastal development can damage coastal habitats such as mangroves and seagrasses, which are essential for fish. This activity can also lead to increased pollution from human activities such as sewage and industrial waste.

8. Lack of Effective Management

Insufficient regulation of fishing activities can lead to overfishing and habitat destruction. Lack of enforcement of fishing regulations can also contribute to overfishing and habitat destruction.

GENERAL FISHERIES MANAGEMENT PLAN

Fish is an important source of nutritious food. There are many reasons for the decline of fish in the world. Some of the important causes of fish decline are Overfishing, indiscriminate fishing of young fish, pollution of water and ignorance of fish culture. The following is an important general management plan, which can go a long way in the conservation of fish in the world.

1. Overfished Water restoration: Most coastal areas and inland waters have overfished, and restocking is necessary if the fish do not disappear entirely. This can be done by transferring small fish from areas well-populated with fish or by introducing new species.

Such young fish should be shielded from predators and allowed to be well-establish before fishing commences.

2. Recognized distinction of Fishing: The killing of immature fish and bottom trawling should be forbidden. In some countries, the size of all fish brought into a port must be checked and offenders can be officially cautioned and fined.

3. Artificial Fertilization of Eggs: Scientists have successfully experimented with the artificial fertilization of eggs in special hatcheries and then transferred them from the breeding ground.

4. Protection from Pollution: Fish cannot survive in polluted water. There should be legislation against those industries responsible for pollution. This step will help tremendously in preserving the fish pollution both in rivers and coastal waters.

5. International Agreement on Fisheries: As fish have no boundaries, it is essential to devise some form of international control systems for overfishing and to minimize the coastal pollution.

6. Research in World Fisheries: Systematic research about fisheries is imperative for the sustainability of this resource. In this direction, research needs to be done about the salinity of oceans, temperature of water, fertility of the micro-organisms or plankton, data on number and type fish caught, fishing method, greater use of fish, sea mammals and other marine products. If all the above steps are taken together, the fish resource may be made more viable and sustainable

FISHERIES IN PAKISTAN

Pakistan stands at 33rd position in the world with respect to fisheries production. Pakistan total fisheries production is 0.79 million tons (marine 0.51 plus inland 0.28 million tons). Total fisheries annual production in Pakistan was reported 660586 metric tons in 2012, according to the world bank collection of development indicators. There are seventy (70) commercial species of fish including sardine, hilsa, shark, mackerel, butter fish, pomfret, sole, tuna, sea bream, jew fish, catfish, and eels. Pakistan is 46th exporter of fish in the world. Top fish which Pakistan exports are sardines, croakers, snappers, pomfrets, shark's, catfish and barracudas.

Pakistan has two types of fish on the bases of geographical location:

1. Marine Fisheries:

Pakistan has a 1,046 km coastline and an Exclusive Economic Zone (EEZ) of 240,000 sq. Major fishing ports are Karachi, Korangi, and Gwadar. Key species of fish are shrimp, mackerel, sardines, tuna, and cephalopods.

2. Freshwater Fisheries:

Pakistan has several major rivers like Indus, Jhelum, Chenab, Ravi, and Sutlej and lakes like Manchar, Keenjhar, and Haleji. The Key species of fish in freshwater resources are carp, catfish, and mahseer.

FISHERIES MANAGEMENT IN PAKISTAN

Pakistan's fisheries management involves regulating and conserving the country's marine and freshwater fisheries resources. Pakistan government has taken the following steps for fish conservation and management:

- Identify Licensing and permits for fishing vessels and gear.
- Formulated the Catch limits and closing seasons to prevent overfishing.
- Adopted control over bottom trawling practices for prevention of unwanted fish.
- Marine protected areas (MPAs) to conserve habitats and biodiversity.
- Monitoring and enforcement through the Pakistan Maritime Security Agency (PMSA) and provincial authorities.
- Overfishing, destructive fishing practices, Habitat degradation and pollution have been controlled by fisheries law implementation.
- Climate change impacts on fish resources have been controlled, mitigated by some extinct through research.
- National Fisheries Policy (2018) aims to promote sustainable fisheries and aquaculture.
- Pakistan Fisheries Development Authority (PFDA) regulates and develops their sector.
- International cooperation with organizations like the Food and Agriculture Organization (FAO) of the United Nations.

CASE STUDIES & PROJECTS FOR FISH CONSERVATION IN PAKISTAN

Some case studies and recent project examples of **fisheries conservation & restoration** in Pakistan (both marine and inland), plus analysis of what was achieved and what gaps remain.

Support to the Fishery Resources Appraisal Project (FRAP)

This project was launched by collaboration of food and agriculture organization of the united nation and Marine Fisheries Department of Pakistan near the Coastal & offshore waters of Pakistan. It aims fish and mangroves conservation and restoration, Capacity building for research institutions and fisheries management bodies.

The appraisal provided a better scientific baseline of marine and mangrove-creek fisheries. It showed that many stocks are over-exploited and called for regulation of fishing effort. Having good data helps identify overexploitation and inform policy.

Community-based fisheries management,

This project was launched over coastal belt and the Pakistan largest seaport: Ganz, Gwadar (Makran Coast, Balochistan). The objective of the project was to control overfish territories to avoid over-exploitation. Participation in managing fishing practices; effort to balance sustainable use against open access.

The case study reports that community managed territory had benefits: more sustainable exploitation, increased local stewardship, better managed conflict. Though quantitative gains (fish stocks, catch per unit effort etc.) are less well documented in that specific study.

Coastal ecosystem restoration & resilience project

Launched by IUCN under Prince Albert II Foundation in mid-2023 in areas of Karachi coast & coastal wetlands: Jiwani Coastal Wetland, Miani Lagoon (Balochistan); Indus Delta (Sindh). The project is designed to enhance resilience of coastal ecosystems and local communities. It includes actions against unsustainable fishing, marine pollution, rising sea level etc. There's also component of small grants, planning & implementation of marine protected areas, ecosystem restoration. Outcomes of the project is that restoration of mangroves is ongoing; small grants for community action; but longer-term outcomes such as fish stock recovery etc. is still to be measured.

Mangrove restoration (Korangi Ecosystem Project)

The location of the project was Korangi / Indus Delta, Sindh coast. Project achieved its goal by, restoring degraded coastal land with mangrove plantations; used nurseries etc.; aimed to rehabilitate mangrove habitats which are important for fisheries (nursery grounds) among other ecosystem services. Over **6,000 hectares** of degraded land have been rehabilitated with mangrove plantations. The restored mangroves will help in stabilizing coastline, storm protection, and supporting local fishery productivity (nurseries etc.).

WATERSHED

Land area that contains an interconnecting network of waterways including water channels, seasonal streams and brooks that all drain into one greater water body (i.e. river, lake or sea). This is a bounded hydrological system and may include high points from mountain top to the lower basin. All living things such as flora, fauna and microorganism of the area are linked by their common water course.

OBJECTIVES OF WATERSHED MANAGEMENT

Watershed management is the rational use of land and water resources for optimum production causing minimum damage to the resources. The main objectives of watershed management are as:

The main objectives of watershed management are:

Environmental Objectives

1. Reduction of erosion and sedimentation for Soil conservation

2. Manage water resources as dams etc. as a sustainable manner to conserve Water.

3. Protect and restore ecosystems for biodiversity conservation.

Socio-Economic Objectives

1. Enhance agricultural productivity, i.e increasing the availability of fodder, fuel wood, timber and raw materials for industries.

2. Sustainable resources use for poverty reduction in rural areas for the development of their lifestyle.

3. To manage the watershed for development activities like domestic water supply, irrigation and hydropower generation.

Hydrological Objectives

1. Regulate water flow to prevent flooding, minimize the risk of droughts and landslides.
2. Water quality improvement by enhancing water quality through pollution reduction.
3. For the Recharge of groundwater aquifers

WATERSHED MANAGEMENT

The set of approaches focuses on development of management plans and implementation of practices regarding the development, conservation and restoration of watershed to enhance its functions and resources. It is a geohydrological unit and drains at a common point. It has been accepted worldwide as a scientific unit for area development.

The watershed can range from a few square kilometers to a few thousand square kilometers in size. Watershed development is the rational utilization of natural resources of soil, water and vegetation for increasing and stabilizing the production of land on a sustainable basis. The development of watersheds will result in soil water table boosting and wells recharge. The watershed-based development approach is undoubtedly an agreeable concept to set the goals, but this demands a massive people's movement to take the village community self-reliant. Watersheds are very often found to be degraded due to uncontrolled, unplanned and unscientific land use activities like overgrazing, deforestation, mining, soil erosion and industrialization etc.

The National Water Policy of Pakistan (NWPP) approved in 2018 provides guidelines for water management, conservation, governance, and watershed management. Numerous measures are necessary for watershed management. Watershed management in Pakistan focuses on conserving water resources, improving agricultural productivity, and mitigating the impacts of climate change. National Water Policy emphasizes efficient water use, particularly in agriculture, which consumes over 93% of the country's water resources. Research focuses on reducing water losses during conveyance and application.

Determining crop water needs is crucial for efficient water use. The Pakistan Council of Research in Water Resources (PCRWR) conducts research on crop water requirements to assist farmers in reducing water wastage. PCRWR is working on watershed management, groundwater recharge, and flood management. Initiatives like the Leaky Dam in Balochistan aim to recharge groundwater, while the Irrigation Advisory Service provides farmers with weekly irrigation recommendations.

Improving irrigation efficiency is critical, as the current system loses over 50% of canal water. Modernizing irrigation systems and promoting water-saving technologies can help address water scarcity challenges. Groundwater is a vital source of water in Pakistan, but over-extraction and inadequate recharge are significant concerns. PCRWR is working on groundwater investigations, demarcation of groundwater quality zones, and recharge of depleted aquifers.

GENERAL MANAGEMENT PLAN FOR ECOSYSTEM-BASED WATERSHED MANAGEMENT

Ecosystem-based watershed management (EBWM) integrates ecological, social, and economic considerations to maintain the health of watersheds. It aims at sustainable use of land, water, and biological resources while reducing risks of degradation and climate impacts.

OBJECTIVES

- Conservation and restoration of watershed ecosystems (forests, wetlands, rivers).
- To ensure sustainable supply of water for domestic, agricultural, and industrial uses.
- Reduction of soil erosion, sedimentation, and flood risks.
- Enhancement of biodiversity conservation and habitat connectivity.
- Promotion of community participation and livelihood improvement.

KEY COMPONENTS OF THE PLAN

Watershed Assessment

- Baseline studies of hydrology, land use, biodiversity, and socio-economic conditions.
- Identification of degraded areas and critical ecosystems (e.g., wetlands, forests).
- Mapping of land cover, soil type, slope, and water flow.

Ecosystem Conservation & Restoration

- Reforestation and afforestation of degraded slopes.
- Wetland and riparian buffer restoration.
- Soil and water conservation practices (terracing, contour plowing, vegetative barriers).
- Control of invasive species and protection of native biodiversity.

Water Resources Management

- Sustainable water allocation between agriculture, domestic, and industry.
- Rainwater harvesting and groundwater recharge measures.
- Pollution control through wastewater treatment and eco-friendly farming.
- Protection of headwaters and aquifer recharge zones.

Climate Change Adaptation & Disaster Risk Reduction

- Early warning systems for floods and droughts.
- Adaptation of nature-based solutions such as mangroves and wetlands improvement for flood control.
- Drought-resilient crop varieties and efficient irrigation systems.
- Community-based disaster risk reduction programs for other awareness sessions.

Community Participation & Livelihoods

- Engagement of local communities in decision-making.
- Promotion of eco-friendly income sources such as agroforestry, ecotourism, fisheries.
- Training in sustainable farming and water-saving practices.
- Inclusion of women and marginalized groups in watershed committees.

Policy, Governance, and Institutions

- Establishment of watershed management councils.
- Integration of watershed plans into local and national development policies.
- Enforcement of land use zoning and environmental regulations.
- Cross-sectoral coordination (agriculture, forestry, water, environment).

Monitoring & Evaluation

- Regular monitoring of water quality, flow, and ecosystem health.
- Socio-economic impact assessments such as income, food security, equity.
- Adaptive management – revising plans based on monitoring outcomes.

WATERSHED MANAGEMENT CASE STUDIES IN PAKISTAN

Mangla Dam Watershed Management Project

The Mangla Dam Watershed Management Project is a notable example of watershed management in Pakistan. Implemented by the Ministry of Water and Power, the project aimed to reduce reservoir sedimentation and promote sustainable land use practices. 4,500 acres of land were afforested, reducing sediment load and increasing water supplies. Check dams, terracing, and silt traps were constructed to control erosion and conserve soil. The project supported community organizations and generated employment opportunities and contributed to poverty reduction.

Tarbela Watershed Management Project

Another significant case study is the Tarbela Watershed Management Project, which focused on protecting the Tarbela Dam reservoir. The project achieved about 96 nurseries were established, and 8,000 acres of land were planted with trees. 2,320 acres of land were protected from erosion with check dams, and 525 acres were terraced. The project also created employment opportunities and supported community development.

RANGELANDS

In pakistani society we called the rangrland, charragah, in pashto we called wursoo. It is an uncultivable land,dominant with grasses, forbs, shrubs and other herbaceous vegetation.The range ecosystem includes physiography, soil vegetation,water, animal life and associted atmosphere.The national commttee on range land management define the ranglands as, “uncultivate areas tha t support natural or seeded herbaceous or shrubby vegetation with or

without trees". Stoddart (a scientist) also define rangeland as , "those areas of the world which by reason of physical limitations low and erratic precipitation, rough topography, poor dranage or extreme temperatures are unsuited to cultivation and which are a source of forage for free ranging native and domestic animals, as well as a source of wood products, water and wildlife."

Rangelands are found in every continent and cover approximately 40% of the earth's land surface. African continent have the most rangelands,because of their arid and dry climates. almost all grasslands and savanas are the identification of this continent. Some of most prominent rangelands of africa are Savannas of East Africa, Kalahari Desert, Sahel Region.Asian prominent rangelands are Mongolian Steppes, Tibetan Plateau. These are the grasslands which cover the half region of asia including Mangolia, Chaina, Russia, India and Tibet. European rangelands and pastures covering Spain, portugal,Mediterranean coasts and Eatern hungary are Alpine Pastures, Iberian Steppes, Hungarian Puszta.North America also have the great geographic ranelands namely Great Plains, Southwestern Rangelands, Canadian Prairies.South America`s range lands include Pampas,Patagonian Steppes, and Cerrado.Australia and Oceania have the grasslands namely, Australian Rangelands, New Zealand High Country.

Out of the total land area of Pakistan, about 50.88 million hactres are grazing lands, which constitute about 57% of the land area of Pakistan. The extent of rangelands in different parts of the country varies. Balochistan has about 97% of its area under grazing lands, while the proportion of grazing land area, out of the total land area in AJK, GB, KP, Punjab and Sindh are 64 %, 61%,35%, 24%, and 21% respectively. About 65% of the land area in the country is in the same category. Their management is under the responsibility of different provincial departments. All these lands are managed by the provincial forest departments.

Rangelands in pakistan are Alpine pastures, Hamalays forests grazing lands,Potohar plateau,Thal desert ranges,Tharparker desert ranges in Sindh,Cholistan ranges,Potohar ranges ,D.G khan ranges ,Koh suleman ranges ,Balochistan plateau ranges.

RANGELANDS MANAGEMENT

Range land management refers to the practices used to maintain and improve the health and productivity of rangelands .Stoddart and his coworkers defined the range management as, "The science and art of optimizing the return from rangelands through the manipulation of range ecosystems." The American society for Rang Management(1964) defined the Range Management as "The art and science of plaining and directing rang use to obtain sustained maximum animal production consistent with perputation of the natural resources."

GOALS AND OBJECTIVES OF RANGELANDS MANAGEMENT

Ecological objectives

1. Maintain or improve vegetation cover: Ensure that vegetation cover is adequate to prevent soil erosion, maintain biodiversity, and support ecosystem services.

2. **Promote biodiversity:** Manage rangelands to conserve and promote biodiversity, including native plant and animal species.

3. Protect soil health: Implement practices that reduce soil erosion, improve soil fertility, and maintain soil structure.

4. Conserve water resources: Manage rangelands to optimize water use efficiency, reduce water pollution, and protect water sources.

Economic objectives

1. Optimize livestock production: Manage rangelands to optimize livestock production, including weight gain, fertility, and mortality rates.

2. Improve economic viability: Ensure that rangelands management is economically viable and sustainable, providing a stable income for landholders and communities.

3. Diversify income streams: Explore alternative income streams, such as ecotourism, carbon sequestration, and wildlife conservation, to reduce dependence on livestock production.

4. Reduce costs and improve efficiency: Implement cost-effective and efficient management practices to reduce costs and improve productivity.

Social objectives

1. Support rural livelihoods: Manage rangelands to support rural livelihoods, including pastoralism, agriculture, and other land-based activities. In pakistan, specially balochistan province approximately fifety percent of population is dependent on rangelands for livestock raring.

2. Promote social justice and equity: Ensure that rangelands management is fair, equitable, and partiiality. It recognizing the rights and interests of all stakeholders, including indigenous communities.

3. Foster community engagement and participation: Encourage community engagement and participation in rangelands management, ensuring that local knowledge and concerns are integrated into decision-making processes.

4. Protect cultural, heritage and traditional practices: Manage rangelands to protect cultural, heritage and traditional practices, including those related to pastoralism, hunting, and gathering.

Components of rangeland management

1) Grazing management
2) Fire management
3) Invasive species management
4) Human activities and land management

GENERAL MANAGEMENT PLAN FOR GRAZING MANAGEMENT

Pakistan has a significant area of rangelands, which are crucial for livestock grazing and biodiversity conservation. Regulating the amount and timing of livestock grazing to prevent overgrazing and allow for vegetation recovery. Effective grazing management is crucial for maintaining healthy rangelands. Here are the key components of grazing management in rangelands:

1) **Grazing Planning**

First step is to determine the planning for grazing management, such as maintaining vegetation cover, promoting biodiversity(as required keystone species of flora and fauna) or improving livestock productivity. The second step is to evaluate the rangeland's vegetation, soil, water, and wildlife resources to determine their capacity to support grazing. Then outlines grazing strategies, including stocking rates, grazing periods, and rest periods.

2) **Stocking Rates**

Stocking rates refer to the number of animals grazing on a specific area of land for a given period. This can be determined by specific units called animal units. To determine the stock rates of a rangeland, the carrying capacity must be taking into account.

In other words we can say that the grazing plan can be that,maximum number of animals inventory in the rangeland which can be supportesd in a sustainable manner .Then to monitor and adjust stocking rates as needed to maintain a balance between grazing pressure and vegetation recovery.

3) **proper animal inventory**

Determning Proper animal inventory and their Grazing periods. factors like vegetation growth rates and animal nutritional needs must be taking into account. Then to establishment periods to allow vegetation to recover and replenish it`s energy reserves. Implementation of rotational grazing systems for the distribution of grazing pressures more evenly and to promote vegetation recovery.

4) **determination of grazing units**

Ensure that water sources are distributed throughout the rangeland to promote even grazing distribution.Salts and other minerals supplements in a way that encourages even grazing distribution. The creation of grazing lanes and trails can facilitate animal movement and reduce soil compaction.

5) **Grazing schedule**

There will be daily, mothly and annual schdules. animal type and grazing intensity and giving proper time for fooder regrowth. Overgrazing and tramupling rusults without specific schedules. Without proper schedule, fertile land may become barren permanently.

6) **Monitoring and Evaluation**

Regular monitoring of rangelands for different aspects like impact of animal grazing,vegetation cover, fertility. soil health indicators such as erosion, compaction and nutrient level and also animal aspects suchas track animal performance indicators like

weight gain, fertility and mortality. Economic viability of the grazing operation, including costs, revenues, and profitability.

7) **Adaptive Management**
grazing management strategies in response to changing environmental conditions, such as droughts or floods. Joint coliboration with other stakeholders, such as neighboring landowners, researchers, and conservation organizations, to share knowledge and best practices.

Animal unit concept in range management

An animal unit (AU) is a standardized measure used to express the grazing equivalent of different types of livestock. It's a way to compare the grazing impact of various animals on a particular piece of land. . This is mostly used as sustainability indicator. Using animal units helps ranchers and land managers make informed decisions about grazing management, ensuring the long-term health and productivity of their land and livestock.

One animal unit is defined as, "A cow with his calf (450 kg) which eats 9.1 kg food for 24 hours is called an animal unit. Animal units are mostly used in natural resource management. It can also be defined as, "One mature cow (1,000 pounds or 450 kg) with a calf Or five sheep or goats Or one horse." This means that one animal unit represents the amount of forage consumed by one of these animal types in a day.

For example, if a ranch has 100 acres of grazing land with a capacity for 50 animal units, they could graze:50 cows with calves or 250 sheep or goats or50 horses.

OUTPUT OF RANGE LAND MANAGEMENT:

Proper range land management can Improve livestock productivity and health

i. It can enhance wildlife habitats and biodiversity
ii. Improve water quality and increase its quantity
iii. It can reduce soil erosion and can improve soil health
iv. Support rural livelihoods and communities
v. Mitigate climate change impacts

By adopting these practices, range land managers can ensure the long-term sustainability and productivity of rangelands.

BARRIERS FOR RANGELANDS MANAGEMENT IN PAKISTAN

In pakistan, there are many barriers for rangelands management as following:

Limitted finance and infrastructure : Insufficient funds and high labour costs for infrastructure, equipment and training. Limitted infrastructure, such as fencing, water points, and road assess can restrict grazing management options.

Low profit margins: Thses practices sometimes may not be economically viable due to low profit margins. The heavy costs and low GDP growth limit the rangelands management in the country.

Environmental barrier: unpredictable weather conditions such as thunderstorms, droughts cam impact grazing management. Due to over activities of humans and trampling of organisms, the furtile land can be deragaded.Soil erosion, compaction, nutrient depletion and water scarcity impacted the grazing management.

Local community barriers: the local community have their own local type management, so they can not allow the outsiders to involve in their local lands.

Lack of awareness, knowledge and skills: the people are not aware of modern management benefits. They follow their tradational management, which have limitted benefits because of limitted knowledge and skills.

Unjudicial occupation: as the lands of the local communities are overlaped, so there is an unjudicil division or even occupied by other powerful communities. They degraded the land by overgrazing and trampling of animals.

Insufficient policies: The government have weak control over rangelands. They can not alllocate proper budget and other incentives to the public. Insufficient policies can not support sustainable grazing management.

Techlonogical barriers:

In the country, there is limitted access and high cost of technology. This is a major barrier to limit the grazing management.

Pest and diseases: presence of pest and diseases can impact grazing management. Some times the pathogens attack a keystone grass species of an ecosystem, so the grass land become degrade.

Wildlife conflicts: conflicts with wildlife, such as predators and competating grazers can impact grazing management.

CAPTER-7 WEATHER AND CLIMATE

Climatology is the scientific study of the atmosphere and the phenomena that we usually refer to as weather. Weather is the state of the atmosphere at a given time and place or the daily or day-to-day atmospheric changes sometimes from hour to hour. Whereas changes in the weather are continuous and sometimes seemingly erratic, it is nevertheless possible to arrive at a generalization of these variations.

Climate is an average weather conditions of an area or environmental conditions of an area for a long period of time almost thirty years. The environmental factors sometimes called weather variables may include quantity of light, temperature, humidity, wind, gases, water etc. Such a description of aggregate weather conditions is termed as climate. It is based on observations that have been accumulated over many decades. Climate is often define simply as “average weather”. In summary therefore, weather deals with the specific while climate deals with a generation of weather events. Climate is what we expect, and weather is what we get.

Difference between meteorology and climatology

Meteorologists focus on forecasting weather; they look at a few basic atmospheric interactions and hope to predict the weather in the next few days. Climatologists take a much larger view of the whole climate/ weather idea. They look at how climates are created and what they do to the environment.

What makes a climate?

Several factors go into making a climate

Temperature: changes throughout the day. It is a variable of daily and few days. It is one of the most important factors of weather and climate.

Pressure: there are large masses of air of high and low pressure across the earth.

Cloud cover: affecting local climates by changing the temperature, i.e. less energy from the sun.

Humidity: measure of water vapor in the surrounding air. It is always proportional to temperature associated with weather.

Wind: the fluctuation in land-sea surface heating creates winds. They can be nice slow breezes and at other times very fast and destructive.

The above factors affect each other. Higher temperatures might increase evaporation of water that would directly increase humidity.

History of Climatology

The study of climatology begins as early the ancient Greek culture. The “kalima” is a Greek word, which means region or zone. The Greek wrote about the atmosphere, as they had

great interest in this subject. In 340 BC, Aristotle wrote “Meteorological”, the first systematic written work on the principles of the subject. The first literature work written by Hippocrates was about “Air, water and places “in 400 BC.

Arab scholars in the 9th and 10th centuries expand on the Greek interest. Renewed interest came in 15th century in Europe with the “age of discovery.” Extended sea voyages led to descriptive reports of “different climates outside of Europe.” Scientific analysis of the atmosphere began in the 17th century with the design of instruments. Italian scientist Galileo invented thermometer in 1593. Another Swiss scientist Lambert invented the hygrometer in 1755 for humidity and moisture measurement in atmosphere. In the 18th century, extensive data collection and description of regional climates began. Explanation of atmospheric phenomena began in the 19th century. The main developments were in the 20th century. The early references are in scientific works, but later climatology evolves as a science.

CONTENTS OF CLIMATOLOGY

Regional: it is the description of climates over selected areas of the earth.

Physical: it involves studying the behavior of weather elements or processes in the atmosphere in terms of physical principles. It emphasizes global energy and water balance regimes of the earth in the atmosphere.

Dynamic: its emphasis on the atmospheric motions of various scales, particularly the general circulation of the atmosphere. As the earth is bent up to 23.5℃ on its axis against sun, the circulation of wind and speed of every moving object through atmosphere is calculating by noting every necessary parameter.

Applied: the application of every climatological knowledge and principles to solve problems that mankind is facing.

Synoptic: it relates to the analysis of local and regional climates and atmospheric circulation.

Historical: it is the study of the development of climate through time.

Paleoclimatology: seeks to reconstruct the past climates by examining records such as ice cores.

Macro climatology: study of climate of very large areas i.e. on global and continental scale.

Meso climatology: study of climates in medium areas such as sub-continental areas or a country.

Micro climatology: study of atmosphere and atmospheric conditions of a small area like a city.

Global temperature and weather measure

Scientists measure global weather using a variety of methods and technologies including,

Weather stations: stations on the ground that record weather data. Nowadays, there are ten thousand weather stations around the world that record these variables.

Weather balloons:

The first time in the 19th century (1885), balloons were used to monitor air currents and temperature. Weather balloons that are launched into the atmosphere with a warm and light air parcel taking all topographical instruments to record weather variables.

Radars: radar systems that use radio waves to record weather data.

Ships and buoys: ships and buoys in the oceans that record weather data such as water and air temperature.

Aircraft: Later in the 20th century, aircraft were started in world war-1 and 2 to monitor the atmosphere.

Satellites: spacecraft that orbit the earth and record weather such as temperature and cloud cover. The geostationary satellites called synchronous meteorological satellites are using for this purpose.

Tree rings and ice cores: natural records of past weather patterns that can be used to reconstruct historical climate data.

Paleoclimate records: records of past climate data that can be used to understand long-term climate trends.

Instrumental records: direct measurements of weather data, such as temperature and precipitation, that are recorded using instruments like thermometers and rain gauges.

ATMOSPHERIC (WEATHER) VARIABLES

1)ATMOSPHERIC TEMPERATURE

Temperature Influences air pressure, wind circulation, and cloud formation. It determines whether precipitation falls as rain, snow, sleet, or hail. Daily highs and lows are the most observed weather elements. Sudden temperature changes can indicate the arrival of weather systems such as thunderstorms and air fronts. The simplest examples are when the rise in temperature during the day due to solar heating occurs, it results in low pressures and when there is seacoast, the heavier air blows to the terrestrial territory to fill the vacancy called sea breeze. In contrast A cold front with heavier fluids lowering local temperatures rapidly.

One of the primary indicators of climate classification on latitudinal bases: tropical, temperate, polar. Temperature Influences ecosystems, vegetation zones, and human activities. It’s also the basic indicator in climate models for projection of future changes in

heatwaves, droughts, and seasonal cycles. Long-term temperature records help detect global warming and climate change trends. Examples are the average annual temperatures in polar regions are below freezing, defining their cold climate. Global average temperature increase of ~1.4°C since pre-industrial times indicates climate change.

2) HUMIDITY

Humidity is the amount of moisture or water vapor present in the air it is the most important aspect of the atmosphere and plays a crucial role in shaping the weather and climate. There are two types of humidity as follows:

Absolute Humidity The mass of water vapor in a given volume of air (usually as grams per cubic meter) is known as absolute humidity:

$$\text{Absolute humidity} = \frac{\text{Mass of water vapor (grams)}}{\text{Volume of air (cubic meters)}}$$

As air moves from one place to another, changes in pressure and temperature cause changes in its volume. When such volume changes occur, the absolute humidity also changes, even if no water vapor is added or removed. Consequently, it is difficult to monitor the water vapor content of a moving mass of air when using the absolute humidity index. Therefore, meteorologists generally prefer to use mixing ratio to express the water vapor content of air.

Relative humidity is a ratio of the air's actual water vapor content compared with the amount of water vapor required for saturation at that temperature and pressure. Thus, relative humidity indicates how near the air is to saturation rather than the actual quantity of water vapor in the air.

The optimal relative humidity for outdoor and some indoor environments typically ranges from 30% to 50%, according to organizations like U.S. environmental protection agency. However, some studies and recommendations suggest a slightly wider range of 40% to 60%. Maintaining humidity within this range helps prevent issues like skin, allergies and mold growth. Relative humidity can be determined as follows:

$$\text{Relative humidity} = \frac{\text{Mixing ratio (amount of water vapor in the air, g/kg)} \times 100}{\text{Saturation mixing ratio (g/kg)}}$$

3) DEW POINT

The dew point is the temperature at which the air's capacity to hold water is reached, causing condensation to occur. We can also be defined as, the temperature at which Air reaches saturation and, hence, is directly related to the actual moisture content of a parcel of air. The dew point is the point at which the air's relative humidity reaches 100%. Dew point is a measure of atmospheric moisture content. It is always equal or lower than the air temperature. When the dew point is high, the air is more humid and when the dew point is

low, the air is drier. E.g. if the air temperature is 25˚C and the dew point is 20˚C, the air is relatively humid. If the air temperature is 25˚C and the dew point is 5˚C, the air is relatively dry.

For most people, an outdoor dewpoint between 50-60 degrees Fahrenheit (10-16 degrees Celsius) is considered comfortable. Dewpoints in this range indicate dry and comfortable air. Dewpoints like in Balochistan regions are always below zero indicating very dry air. Higher dew points, like those in 60, can feel humid and sticky, while dew points above 70 degrees Fahrenheit (21 degrees Celsius) are often considered oppressive and uncomfortable.

Differences between dew and frost

The Dew point is the temperature at which the water vapors in a sample of air, condenses into liquid water at the same rate at which it evaporates. In contrast, when the temperature is low enough, the dew takes the form of ice, this is called frost. Frost consists of ice crystals that are deposited on cold surfaces. The formation of frost is the same as dew. The difference is that the dewpoint of frost is below the freezing temperature.

Difference of Mist and fog

Mist consists of very fine microscopic, condensed water droplets. These are held in suspension in the air because of their small size. The mist often forms at a very low ground level, and the droplets form a thin, fine veil which hinders the visibility. The visibility is obscure but still exceeds one (1) km.

In contrast, Fog contains small, condensed water droplets which are larger than those in mist. It forms a thick veil which causes poor visibility below one (1) km. Thus, there is a physical difference between mist and fog. There is the same physical difference between fog and clouds. Fog is nearer to the ground while clouds are higher in the atmosphere. In other words, we can say that clouds are condensed at higher altitudes above the ground.

ATMOSPHERIC PRESSURE

The force exerted by air molecules as they collide with a surface or atmospheric pressure is the force per unit area or the weight exerted by the atmosphere on a surface.

Three factors that can affect Air pressure are elevation, temperature and humidity.

Temperature and humidity are inversely proportional to air pressure. As temperature increases, warm air has high moisture contents and molecules have high kinetic energy, so air expands and as a result the pressure decreases. The pressure is also inverse to altitude and elevation. At higher altitudes, the pressure will be very low as compared to ground level. In this regard the standard atmospheric temperature and pressure can be measured on land-sea surface.

Unlike temperature, pressure decreases exponentially with altitude. Traces of the atmosphere can be detected as far as 500 km above Earth's surface, but 80 percent of the atmosphere's mass is contained within the 18 km closest to the surface.

Atmospheric pressure is generally measured in millibars (mb); this unit of measurement is equivalent to 1 gram per centimeter squared (1 g/cm2). Other units are occasionally used, such as bars, atmospheres, or millimeters of mercury. The correspondence between these units is shown below.

1.013 bar = 1013 millibars = 1 atm= 760 mm Hg

WIND SPEED AND DIRECTION

In climatology, wind speed and direction are treated as essential variables that describe the movement of air within the atmosphere over long periods of time. Wind speed refers to how fast the air is moving horizontally, while wind direction indicates the compass direction from which the wind originates. Together, these elements help climatologists understand how energy, heat, and moisture are redistributed across the Earth.

Over decades and centuries, the study of wind speed and direction provides insights into large-scale circulation patterns such as the trade winds, westerlies, and monsoons. These patterns shape regional climates by controlling rainfall, humidity, and temperature distribution. For instance, seasonal changes in wind direction are responsible for the South Asian monsoon, which brings wet summers and dry winters, while strong and persistent trade winds influence tropical climates and ocean currents.

Climatologists also use long-term averages of wind speed and direction to identify prevailing winds in a region. Such data are critical for understanding drought cycles, storm intensity, dust transport, and even renewable energy potential from wind. Shifts in these wind characteristics can serve as indicators of broader climate change, as seen in the altered behavior of jet streams and monsoonal systems in recent decades. In short, wind speed and direction in climatology are not viewed only as daily weather conditions but as long-term drivers of regional and global climate systems, influencing ecosystems, agriculture, and human livelihoods.

WIND CHILL /WIND FACTOR

Wind chill is the sensation of cold produced by the wind for a given ambient air temperature on exposed skin as the air motion accelerates the rate of heat transfer from the body to the surrounding atmosphere.

The wind chill temperature is how cold people and animals feel when outside. Wind chill is based on the rate of heat loss from exposed skin caused by wind and cold. As the wind increases, it draws heat from the body, driving down skin temperature and eventually the internal body temperature.

UV INDEX

The UV index is a linear scale that measures the intensity of UV radiation with respect to sunburn. For example, assuming similar spectral power distributions, radiation with a UV index of 12 is twice as intense as radiation at a UV index of 6.

According to the online weather watch of UK, The UV Index is a forecast of the amount of skin damaging UV radiation expected to reach the earth's surface at the time when the sun is highest in the sky (around midday). The amount of UV radiation reaching the surface is primarily related to the elevation of the sun in the sky, the amount of ozone in the stratosphere, and the amounts of cloud cover. However, thick clouds can greatly reduce ultraviolet radiation levels and, surprisingly, certain types of thin cloud can magnify the ultraviolet radiation strength.

From 0 to 2, You can safely enjoy being outside,3 t0 7 you must Seek shade during midday hours! Slip on a shirt, slop on sunscreen and used a cap in outdoor sunny environments. Above eight, we must Avoid being outside during midday hours! Make sure we seek shade Shirt, sunscreen and a hat.
The higher the UV Index, the greater the rate of skin damaging and eye damaging. Consequently, the higher the UV Index, the smaller the time it takes before skin or eye damage occurs. The skin type is also a factor for sensation of UV index, according to the skin type table formulated by weather departments, white skins are highly sensitive, naturally brown skins have medium to low risks while naturally black skins have medium to no risks on suns radiations density and frequency.

CLOUD COVER

Clouds formation consists of three basic steps as follows:

Evaporation & Condensation

Sensible heat is transferred by the processes of conduction and convection. Conduction transfers energy within a substance, and convection transfers energy through the vertical movement of the heated substance. Latent heat is the transfer of energy by transforming the substance itself. Water could exist as liquid, gas or solid. The transformation from liquid to gas is called evaporation; the reverse process, from gas to liquid, is called condensation; from liquid to solid is known as solidification (freezing); and from solid to liquid, fusion (melting). Water can also be transformed directly from solid to gas (sublimation), or the reverse, through a process called deposition. These various processes are parts of clouds formation.

Clouds formation

Clouds are formed when air contains as much water vapor (gas) as it can hold. This is called the saturation point, and it can be reached in two ways. First, moisture accumulates until it reaches the maximum amount the volume of air can hold. The other method reduces the temperature of the moisture filled air, which in turn lowers the amount of moisture it can contain. Saturation, therefore, is reached through evaporation and condensation, respectively. When saturation occurs, moisture becomes visible water droplets in the form of fog and clouds.

Cloud Forms

Clouds are classified based on how they appear when viewed from Earth’s surface. The basic forms or shapes are:

***Cirrus* (*cirriform*)** clouds are high, white, and thin. They form delicate veil-like patches or wisplike strands and often have a feathery appearance.

***Cumulus* (*cumuliform*)** clouds consist of globular cloud masses that are often described as cottonlike in appearance. Normally cumulus clouds exhibit a flat base and appear as rising domes or towers. Cumulus clouds form within a layer of the atmosphere where there is some convection and rising air.

***Stratus* (*stratiform*)** clouds consist of sheets or layers (*strata*) that cover much or all of the sky. Although there may be minor breaks, there are no distinct individual cloud units. All clouds have at least one of these three basic forms, and some are a combination of two of them; for example, stratocumulus clouds are mostly sheetlike structures composed of long parallel rolls or broken globular patches.

In addition, the term **nimbus** (Latin for "violent rain") is used in the name of a cloud that is a major producer of precipitation. Thus, *nimbostratus* denotes a flat-lying rain cloud.

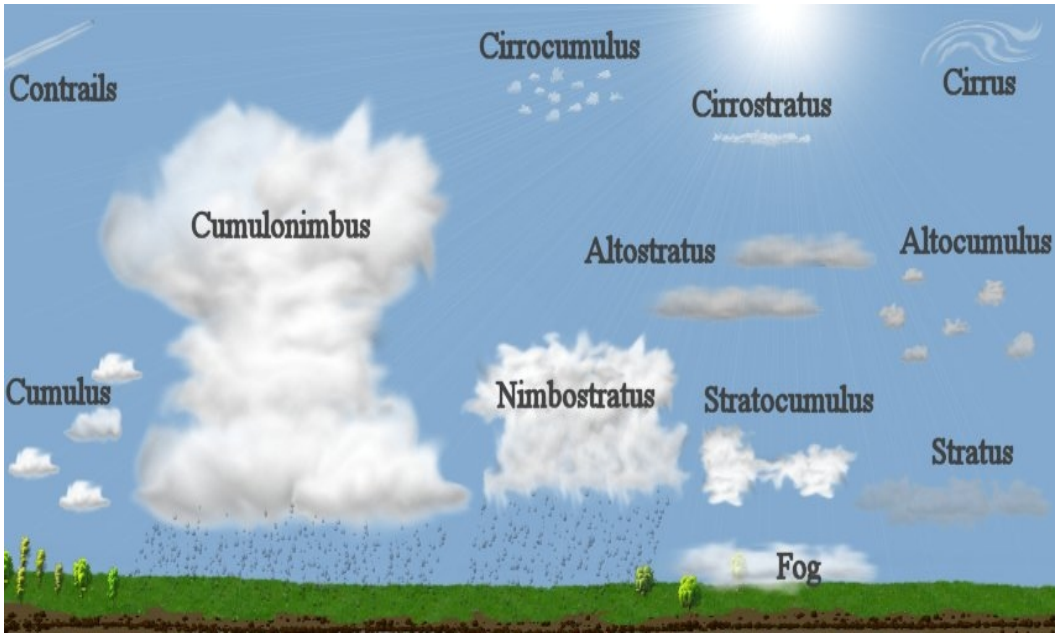
Cloud Height

The second aspect of cloud classification is height. It recognizes three levels: high, middle, and low. High clouds form in the highest and coldest region of the troposphere and normally have bases above 6000 meters (20,000 feet). Temperatures at these altitudes are usually below freezing, so the high clouds are generally composed of ice crystals or supercooled water droplets. Middle clouds occupy heights from 2000 to 6000 meters (6500 to 20,000 feet) and may be composed of water droplets or ice crystals depending on the time of year and temperature profile of the atmosphere. Low clouds form nearer to Earth's surface up to an altitude of about 2000 meters (6500 feet) and are generally composed of water droplets. These altitudes may vary somewhat according to season of the year and latitude. The family of high clouds above 6000 meters include *cirrus*, *cirrostratus*, and *cirrocumulus*. Low temperatures and small quantities of water vapor present at high altitudes result in high clouds that are thin, white, and made up primarily of ice crystals.

Cirrus (Ci) clouds are composed of delicate, icy filaments. Winds aloft often cause these fibrous ice trails to bend or curl. Cirrus clouds with hooked filaments are called "mares' tails".

Cirrostratus (Cs) are transparent, whitish cloud veils with a fibrous or sometimes smooth appearance that may cover much or all the sky. These clouds are easily recognized when they produce a halo around the Sun or Moon. Occasionally, cirrostratus clouds are so thin and transparent that they are barely discernible.

Cirrocumulus (Cc) clouds appear as white patches composed of small cells or ripples. These small globules, which may be merged or separate, are often arranged in a pattern that resembles fish scales. When this occurs, it is commonly called "mackerel sky." Although high clouds are generally not precipitation makers, when cirrus clouds give way to cirrocumulus clouds, they may warn of impending stormy weather.



PRECIPITATION

The World Meteorological Organization (WMO) defines precipitation as any water that forms in the Earth's atmosphere and falls to the ground, encompassing forms like rain, snow, and sleet, and playing a key role in the global water cycle. Precipitation is a key part of the Earth's water cycle and a key factor in determining climate, vegetation patterns, and water availability across the globe. There are many types of Precipitation, but the common ones are as follows:

Rainfall

Rainfall is unevenly distributed across the Earth due to differences in latitude, atmospheric circulation, topography, and proximity to oceans. The global western region of the world such as Indian regions receives the highest rainfall due to monsoons of Hamalian range. So, these regions are highly under threat of heavy rain and flesh floods. Cherrapunji in India (Meghalaya Hills) receiving 10,000–11,800 mm (400–465 inches) annually due to monsoon winds striking the Khasi Hills. This region and all such regions of the world are typically influenced by orographic uplift (moist winds forced up mountains) and monsoonal systems. Minimum Rainfall is receiving by desert regions. Atacama Desert in Chile is the driest desert, with places like Arica and Iquique receiving less than 1 mm per year; some weather stations have recorded no measurable rainfall for decades.

Snow

Snow is a form of solid precipitation that occurs when atmospheric temperatures are at or below 0°C (32°F) and water vapor condenses directly into ice crystals. As a weather variable, snow reflects short-term changes in the atmosphere and directly influences local weather conditions.

Snow cover is a long-term climatic indicator. Its persistence, thickness, and extent help regulate the Earth's energy balance. Snow reflects 70–90% of incoming solar radiation, cooling the Earth's surface.

On worldwide distribution of this precipitation, the Arctic (Greenland, Northern Canada, Siberia) and Antarctic regions have the heaviest and most persistent snow and ice cover. Mid-latitudes such as North America (Rockies, Great Plains), Europe (Alps, Scandinavia, Russia), and Asia (Himalayas, Tibetan Plateau), Snow cover is highly variable and sensitive to seasonal shifts. The Tropical and Subtropical Regions receives very limited snow even the highest mountainous regions such as the Andes, Himalayas, Kilimanjaro, and Mount Kenya. These snowpacks are crucial for downstream water supply.

Sleet

Sleet is a form of precipitation that occurs when raindrops freeze into small ice pellets before reaching the ground. It typically forms when a layer of warm air is sandwiched between two cold layers in the atmosphere, causing partial melting and refreezing of falling snow. As a weather parameter, sleet influences visibility, surface temperature, and road conditions, often signaling transitional weather between rain and snow. In climate studies, the frequency and intensity of sleet events help indicate regional temperature fluctuations and shifts in precipitation patterns due to climate change, especially in temperate and mid-latitude regions.

Hail

Hail is a type of solid precipitation consisting of balls or irregular lumps of ice that form within strong thunderstorm clouds when updrafts repeatedly lift water droplets into extremely cold regions of the atmosphere. It is an important weather parameter as it indicates severe convective activity and atmospheric instability. Hailstorms can cause significant damage to crops, property, and infrastructure, making it a critical factor in weather forecasting and disaster management. From a climate perspective, the occurrence and size of hailstones provide insight into storm intensity and can reflect broader climatic changes, such as shifts in temperature and moisture patterns associated with global warming.

SUN'S ENERGY BALANCE

The energy balance on land and Earth refers to the balance between the energy input from the sun and the energy output back into space. The earth maintains its heat balance within narrow limits, due to complex mechanisms of energy-transfer. Hence, optimum climatic conditions are maintained for supporting life. The sun radiates energy, like a black body at 6000°kilven. Out of solar radiations reaching the earth, 92% consists of radiations in the range 315 to 1400nm. 45% of this is in visible region (400-700 nm). The earth absorbs radiations mainly in the visible range and emits radiation in infra-red region (2-40μm).

Net energy balance is the input minus output, but there is a fall in energy balance, because the stored energy in the form of ocean heat, land and atmosphere and melting ice and snow

is not added. This is crucial for maintaining the earth's climate and weather patterns. Any imbalance can lead to warming or cooling trends.

HEAT TRANSFER

Heating is the only form of energy to run the world's weather machine. It always flows from high to low as water flows from high to low pressure. This transfer of energy in the form of heat is very important in climatology. There are three ways to transfer heat energy through the atmosphere.

Conduction

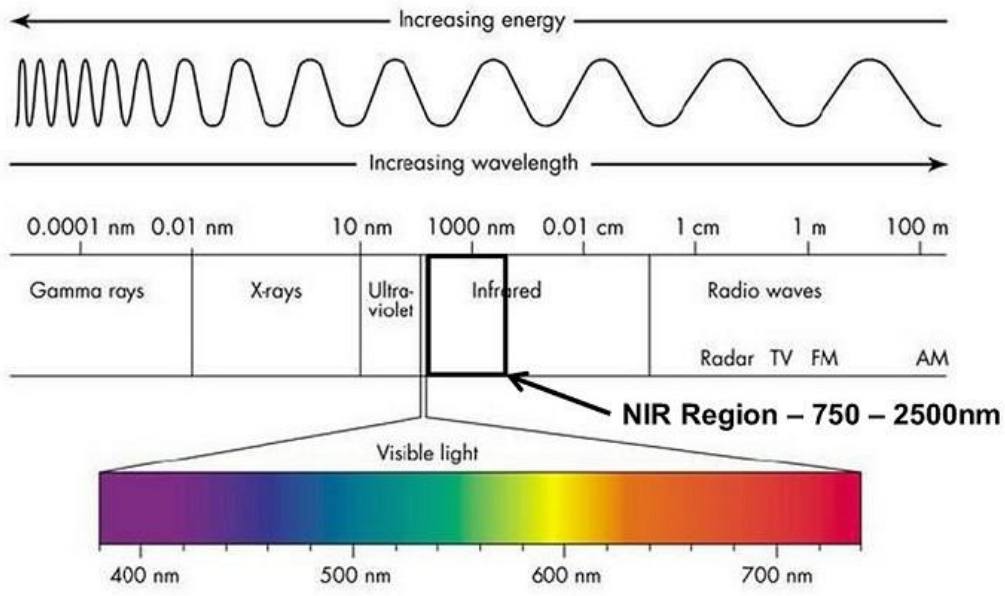
This is a type of heat transfer from molecule to molecule within a substance unlike the transfer of matter from one place to another. Air is extremely poor conductor of heat; therefore, conduction is only important in the atmosphere within the first several millimeters closest to the surface. This makes a question, how then does the air transfer energy from one region to another?

Convection

This is a type of heat transfer through fluid motion (gases and water). The whole matter is shifted from one region to another for heat transfer. As gases and liquids move freely making it possible to set up warm and cold currents. The warm air expends, because it is less dense than the surrounding cooler air, becomes buoyant and rises. Clouds formation in the atmosphere can mainly take place due to the change in heat energy in the atmosphere through the process of atmospheric convection. These first two require a physical substance which may be solid, liquid or gas.

Radiation

Energy in the form of waves such as electromagnetic, light, heat and sound. This type of heat transfer can be observed on sunny days when sunlight is absorbed in our face and hands. The **electromagnetic spectrum** ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). There are several regions of the electromagnetic spectrum. Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation.



The light which our eyes can detect is part of the visible Spectrum. It is important to recognize how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us which is "invisible" to our eyes but can be detected by other remote sensing instruments and used to our advantage. The visible wavelengths cover a range from approximately 0.4to 0. 7µm.The Longest Visible Wavelength is red and the shortest is violet. Common wavelengths of what we perceive as particular colors from the visible portion of the spectrum are listed below. It is important to note that this is the only portion of the spectrum we can associate with the concept of colors.

Color	From(µm)	To (µm)
Violet:	0.4 -	0.446
Blue:	0.446 -	0.500
Green	0.500	0.592
Yellow	0.578	0.592
Orange	0.592	0.620
Red	0.620	0.7

Blue, green, and red are the primary colors or wavelengths of the visible spectrum. They are defined as such because no single primary color can be created from the other two, but all other colors can be formed by combining blue, green, and red in various proportions. Although we see sunlight as a uniform or homogeneous color, it is composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum. The visible portion of this radiation can be shown in its component colors when

sunlight is passed through a prism, which bends the light in differing amounts according to wavelength.

SUN'S RADIATIONS UNEVEN HEATING AND WINDS FORMATION

This is a popular belief that warm air rises. The uneven heating of the land-sea surface by sun energy creates the warm lighter air to rise upward and left vacancy behind, to fill this vacancy, the heavier air blowing to fill the vacancy. This is the natural mechanism on which the global weather machine runs. This motion plays a crucial role in shaping our weather and climate.

winds, which leads to the formation of clouds in the atmosphere. This vertical motion in the atmosphere is also a source for horizontal winds on which world trade depends. Another mechanism for air to rise is due to physical barrier, this can be a mountain. Air can be forced upward or downward when it encounters it. This is called an orographic uplift. Orography refers to the uneven shape of the earth. When wind intersects a mountain or hill, it is simply pushed upward. On the down-wind or lee side of mountain, air moves downward with changing temperatures. Vertical motions in the atmosphere are critical for aviation because of their role in the production of turbulence, cloud formation and associated phenomena.

Earth's surface heating depends on albedo of radiation. High albedo has low heating and high reflectivity. Low albedos have more heating, I.e more absorption of heat. When heated air rises from earth, it expends in atmosphere by convection. The air expends having lower density than the surrounding air and begins to rise.

FACTORS INFLUENCING AIR MOTION AND CONTROL WINDS

The wind discussed as above is the pressure gradient between high and low pressure. Air have the tendency to move from low pressure regions to high pressure regions. The lighter warm air rises to create low pressure center. To fill the low-pressure region, air blowing in much speed called winds. Once created, winds are controlled by a combination of forces as follows:

1) Pressure gradient force
2) The Coriolis force
3) Fraction

PRESSURE GRADIENT FORCE

It is the force that generates winds results from horizontal pressure differences. The underlying cause of pressure differences. is simply unequally heating of earth's land-sea surface. Pressure data are shown on surface weather maps by means isobars. Thise are the lines that connect places of equal air pressure. The spacing of isobars indicates the amount of pressure change occurring over a given distance and is expressed as the pressure gradient. The understand the pressure gradient force, we take the example of sea breeze, we assume that temperatures and pressures do not vary horizontally at any level just before sun rise. This assumption is shown by the horizontal pressure surfaces that indicate equal

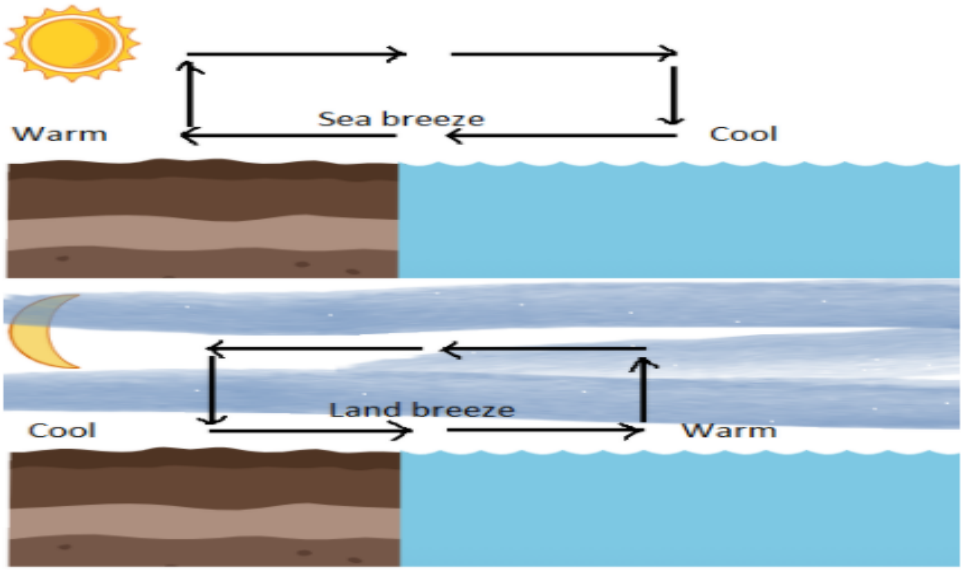
pressure at equal heights, because there is no horizontal variation in pressure, in other words we say that there is zero pressure gradient, so there are no winds.

After sunrise the unequal rates at which land and water heat will initiate pressure differences and therefore airflows. Surface temperatures over the ocean change only slightly, whereas land surfaces and the air above can be substantially warmed during the day, heating the land warms the air. The resultant horizontal pressure gradient causes the air to move from the land towards the ocean. The warmer air moves over the ocean, cools and sinks. This creates a high-pressure area over the ocean, where the air is collecting. Now the pressure near the ocean surface is greater than near the land surface. Thus, PGF is created that causes air near the surface to move from the ocean to the land is sea breeze.

Land and sea breeze

Land and sea breeze are local wind patterns. During the day, the land warms faster than the sea. Warm air rises over the land and cooler air flows into the land from over the sea to replace it. This is a sea breeze, which is cool.

At night, the land cools faster than the sea the heavier cool air flows away from the land towards the sea causing a land breeze, to replace the lighter warm air over the ocean and sea. These winds are of high importance because they help to regulate the local climate conditions, they also influence the formation of clouds and precipitation.



Sea Breeze and Land Breeze

THE CORIOLIS FORCE

Earth's rotation results in the fact that we experience an apparent force, which acts on any object moving free of the earth's surface to deflect from their intended path. The Coriolis effect was described by the 19th-century French physicist and mathematician Gustave-Gaspard de Coriolis in 1835. He formulated theories of fluid dynamics through studying waterwheels and realized the same theories could be applied to the motion of fluids on the surface of the Earth.

These freely moving objects may include aircraft, ballistic missiles and long-range artillery. This force also affects the natural global winds patterns. It deflects the direction of the wind to the right in the northern hemisphere and to the left in the southern hemisphere. This is why the wind-flow around low and high-pressure systems circulates in opposing directions in each hemisphere. The Coriolis force is almost zero at the equator, this is because on the equator, the direction of motion is parallel to the axis of earth's rotation or in other words the rotation velocity vector is parallel to the equator resulting no deflection. Coriolis force increases with latitude. At the poles, the Coriolis force is strongest, because the earth's rotational speed changes significantly with latitude. So, to summarize that a moving object experiences less Coriolis force nearer to the equator than at poles.

An example of the Coriolis effect can be demonstrated by looking at a typical playground roundabout. If you are standing in the center of a spinning roundabout (spinning anticlockwise) and attempt to throw a ball, it will appear to curve to the right, when in fact it is travelling in a straight line to anyone watching who is not on the roundabout. This is like what happens in the northern hemisphere of the Earth, where winds are deflected to the right. This deflection is a major factor in explaining why winds blow anticlockwise around low pressure and clockwise around high pressure in the northern hemisphere and vice versa in the southern hemisphere. Without the Coriolis effect air would simply flow directly from areas of high pressure to areas of low pressure.

FRICTION

Friction and drag for winds may be a physical barrier like a hill or mountain, forests and cities. Friction between the air and the ground slows winds. The higher above the surface the faster the wind will blow. Friction causes winds to change direction, leading to the formation of weather patterns like sea breezes and mountain-valley breezes. It also changes winds direction, impacts on the development of high- and low-pressure systems, fronts and storms.

TYPES OF HORIZONTAL WINDS

TRADE WINDS

Trade winds can be defined as the wind that flows towards the equator from the north-east in the Northern Hemisphere or from the south-east in the Southern Hemisphere. These are also known as tropical Easterlies and are known for their consistency in force and direction. Known to sailors around the world, the trade winds and associated ocean currents helped early sailing ships from European and African ports make their journeys to the Americas. Likewise, the trade wind also drives sailing vessels from the Americas toward Asia. Even now, commercial ships use "the trades" and the currents the winds produce to hasten their oceanic voyages.

How do these commerce-friendly winds form? Between about 30 degrees north and 30 degrees south of the equator, in a region called the horse latitudes. The Earth's rotation causes air to slant toward the equator in a southwesterly direction in the northern hemisphere and in a northwesterly direction in the southern hemisphere, which is called the Coriolis effect. The Coriolis Effect, in combination with an area of high pressure, causes the prevailing winds i.e the trade winds; to move from east to west on both sides of the equator across this 60-degree "belt."

As the wind blows to about five degrees north and south of the equator, both air and ocean currents come to a halt in a band of hot, dry air. This ten (10) degree belt around Earth's midsection is called the inter tropical convergence zone (ICTZ), more commonly known as the doldrums. Intense solar heat in the doldrums warms and moistens the trade winds, thrusting air upwards into the atmosphere like a hot air balloon. As the air rises, it cools, causing persistent bands of showers and storms in the tropics and rainforests. The rising air masses move toward the poles, then sink back toward Earth's surface near the horse latitudes. The sinking air triggers the calm trade winds and little precipitation, completing the cycle.

WESTERLIES

The winds blow from the west towards the east in the middle latitudes between 30° and 60° latitude in both northern and southern hemispheres. These winds get their name from their direction of origin. These are blown from the horse latitudes towards the poles. In the Northern Hemisphere, these are predominantly from the south-west and in the Southern Hemisphere, they are from the north-west. The weather patterns in the United States and Canada are due to westerlies.

EASTERLIES

The easterlies or polar easterlies are located between 60° and 90° latitude in both northern and southern hemispheres and are named after the direction they originate from. These are formed when the cool air from the poles sinks and moves towards the equator. The winds are curved towards the west by the Coriolis effect. These winds are important for sailors.

THE VERTICAL MOTION IN THE ATMOSPHERE

TROPICAL CYCLONE

A tropical cyclone is a generic (basic) term used to describe a rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical water and has clouds, low level circulation. The term tropical cyclone refers to the geographical origin of these systems, which form almost exclusively over tropical seas and over large bodies of relatively warm water of about 27 degrees Celsius. They derive their energy through the evaporation of water from the ocean surface, which ultimately condenses into clouds and rain when moist air rises and cools to saturation.

Hurricanes, cyclones and typhoons are all the same weather phenomena, we just use different names for these storms in different places. In the Atlantic and North Pacific (Gulf of Mexico, Gulf of California, USA, North America), the term Hurricane is used. In the North-west Pacific (Chaina), the term Typhoon is used. In the North and East Australia., the term willy-willy is used. In the south-pacific and Indian ocean, it is called a Cyclone.

In modern times, on average around 80 to 90 named tropical cyclones form each year around the world, over half of which develop hurricane-forced winds of 120 km/h or 75 mph) or more. A hurricane is the biggest and most violent of storm on earth can be 900 km across (sometimes 1000-2000km). Once a tropical storm reaches a maximum sustained wind speed of 74 miles per hour or higher, i.e. 125 km/h, it is then classified as a hurricane, typhoon or cyclone. The wind speed near the center is always more than 120 km/h and sometimes reaches 240 km/h. Hurricanes can form between 190 to 775 km/h, north and south of the equator.

The strong rotating winds of a tropical cyclone are a result of the conservation of angular momentum imparted by the earth's rotation as air flows inwards toward the axis of rotation. As a result, cyclones rarely form within 5° of the equator. Tropical cyclones are very rare in the South Atlantic due to consistently strong wind shear and a weak ICTZ. In contrast, the African easterly jets and areas of atmospheric instability give rise to cyclones in the Atlantic Ocean and Caribbean Sea.

TROPICAL CYCLONE CLASSIFICATION (BASED ON WIND SPEED)

Before it can become a cyclone, it must pass through four distinct stages:

- **Tropical depression**
  this is a storm with maximum sustained winds of 38 Miles per hour or less
- **Tropical storm**
  This is a storm with maximum sustained winds of 39-73 Miles per hour.
- **Hurricane**

  A tropical cyclone with maximum sustained winds of 74 MPH or higher.

- **Major hurricane**
  A tropical cyclone with maximum sustained winds of 111 MPH or higher. In this storm, major destruction takes place.

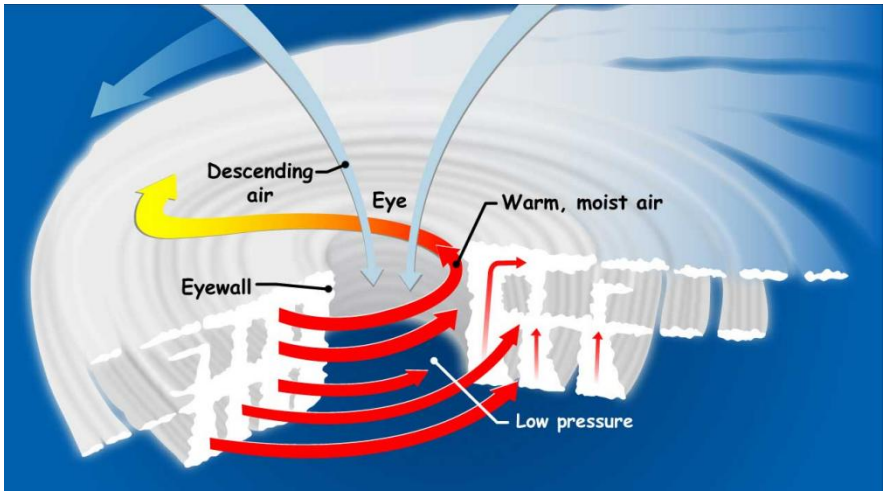
FORMATION OF A CYCLONE

There are a few required favorable conditions for cyclone formation. The ingredients for the storm include free existing weather disturbance, warm tropical ocean water, moisture and relatively high winds. If the right conditions exist long enough, they can combine to produce the violent winds, huge waves, tropical rain and floods.
There are five categories for a tropical cyclone:
Saffir and Simpson winds scale
74-95 MPH: in this category, very dangerous winds, which produce some damage.
96-110 MPH: it has extremely dangerous winds and will cause extensive damage.
111-129 MPH: in this category, due to very high winds, devastating damage will occur.
130-156 MPH: during this storm catastrophic damage will occur.
157 and exceed: this storm will known as category five and can cause more catastrophic damage.

TROPICAL CYCLONE DEVELOPMENT PROCESS

When a cluster of thunderstorms develops or moves into a disturbing atmospheric environment, the disturbances can be more organized. This led to the formation of a tropical depression. Warm water is one of the most important contributors to the formation of cyclones because warm water acts as a fuel for the storm.
As water in the form of vapors rises, it cools down and once saturation is reached, the water vapors condense into liquid water as clouds. During the process of condensation, the heat is released known as heat of vaporization. The process warms the atmosphere, making the air lighter and causing it to rise further. As this occurs, more air must move in near the surface to take its place and fill the vacancy. This inflowing air will begin to rotate under the influence of Coriolis force, developing cyclones.
The Coriolis force have zero effect on the equator, so there is no cyclone formation. The tropical cyclones originate between 8 to 25 degrees North and South of the equator in both hemispheres. Unlike mid-latitude cyclones, tropical cyclones are homogenous with no fronts.
Eye of the storm
The eye of a tropical cyclone is a relatively calm region at the center of the storm. It is a circular area with low pressure. Its diameter is about 20-40 km with background of spiraling clouds about 12 km high. Inside the eye, there is clear skies with little to no clouds, almost no wind and the air is warm as compared to the surroundings. The highest velocities and heaviest rainfall are also recorded adjacent to the center of the tropical cyclone.

Structure of tropical cyclone with central eye
Under the Coriolis force and due to the anti-clockwise rotation of earth, every moving object will deflect to the right (clockwise) in the northern hemisphere and to the left (anti-clockwise) in the southern hemisphere. The following is the structure of a tropical cyclone with its eye, eyewall, rainbands and outer rainbands etc.



Tracks of tropical cyclones

After its origin, a tropical cyclone moves slowly at first, usually moving from east to west in low latitudes. As it gains strength, the speed increases and its path under the effect of Coriolis force curves gradually towards the subtropical and temperate zones. If the storm remains over warm water, it can grow in intensity. A storm can travel northwards along the coasts of the continents over warm water but dissipates rapidly when it moves over the cold water. If it moves over land, it increases friction with the land surface and loss of the energy supply causes the storm to dissolve quickly. Cyclones always occur on the western margins of the oceans over warm tropical water.

On average, there are general regions of the highest frequency of tropical cyclones.

1) The Caribbean Sea and the Gulf of Mexico.
2) The Northeastern Pacific Ocean. e.g. central America etc.
3) The northwestern pacific from Philippines to the east China sea.
4) Southwestern Pacific Ocean e.g. Australia etc.
5) North Indian Ocean in the Bay of Bengal and the Arabian sea.
6) South Indian Ocean; east of Madagascar.

In these regions, the cyclones mostly occur in the late summer and autumn i.e from October to November. It is very interesting to note that the tropical cyclones do not occur in the south Atlantic Ocean. It is because the equatorial convergence zone does not migrate far enough south to provide the necessary convergence and Coriolis affect.

If the sun heated the earth evenly and the land and sea were warmed and cooled equally everywhere, there would be no wind. But this is not what happens. Some places are warmer than others globally and so air is denser in some places. Winds help in the distribution of heat globally.

The sun rays are directly almost overhead near the equator at noon. It shines very intensely because its rays are concentrated. Near the Arctic and Antarctica, the sky even in summer, its rays are less intense because they are spread over a bigger area. This is why it is warmer at the equator than the north and south poles. Therefore, there is unequal distribution of global heat.

The equator becomes very hot and then this hot air rising inti the upper atmosphere. This vertically rising air then moves towards the poles, where it would become very cold and sinks and then horizontally near the ground return to the equator. So, one large area of high pressure would be at each of the poles with large belt of low pressure around the equator. but however, the cause is different because of the reasons that the earth rotates, and its axis is tilted about 23 and half degrees, and there is more land mass in the northern hemisphere than the southern hemisphere. The actual global pattern is much more complicated in this cause, instead of one large circulation between the poles and the equator, there are three circulations as following.

HADLY CELL

Low latitude air movement toward the equator (horizontal movement) with poleward (vertical movement) creates cumulonimbus clouds. This dominates over tropical and subtropical climates.

FERREL CELL

This is the mid-latitude circulation cell. The air flows towards polewards and eastwards near the surface and equatorward and westward at a higher level.

Unlike the vertical circulation of equator, which creates a cyclone, this circulation form air fronts, which creates mid-latitudes cyclones.

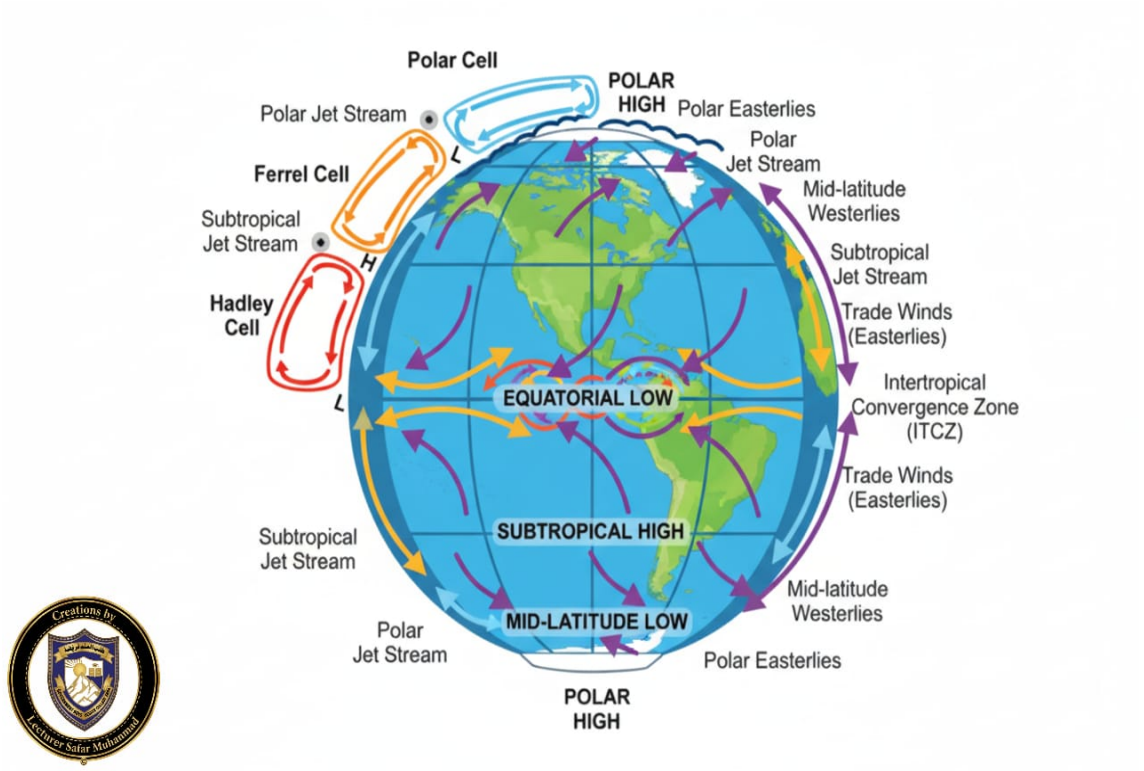
POLAR CELL

Polar cells are locating near the poles, typically within the arctic and Antarctic circles. These are associated with high pressure near the poles. The polar cells rotate from high to low pressure, creating a circulation pattern that derives air from the poles towards the equator.

Air over the equator, rises, diverges and travels towards the poles. Over the poles, the air sinks because it losses heat and become heavier. So, these cells transfer the heat between equator and poles to regulate the world climate.

Between each of these circulation cells (vertical air movement), air bands (winds horizontal movements) of high and low pressure at the surface, the high-pressure bands are locating about 30˚ north and south latitudes and at each pole.

The low-pressure bands are found at the equator and 50-60 degrees north and south latitudes.



SOCIAL RELEVANCE OF TROPICAL CYCLONE

The tropical cyclones are the most violent and destructive types of storms. According to the meteorologists that the by far the greatest damage to life and property is caused by tropical cyclones. The following are some examples of worldwide tropical cyclones that occurred in the near past:

Bangel cyclone: occurred in the Bay of Bengal to Gangeya River in India on 13 November 1970. Wind velocity was 200 kilometers per hour and sea water height was 12 meters.

Rita cyclone: occurred in New Orleans, Houston and Texas in USA in September,2005. The intensity of the storm was so high that the entire population was evacuated.

Sandy hurricane: on the date of 29 October 2012, the North America mostly USA and some parts of Canada was under the influence of this hurricane. One hundred casualties and the commercial city New York was in great danger as several parts of the city were submerged under water.

WORLD CLIMATIC ZONES AND THEIR CLIMATIC DATA

A major ecological community or a large geographical area with its specific and complex flora and associated fauna is called a biome. Or a large terrestrial or aquatic ecosystem characterized by specific plant communities and formations, usually named after the dominant vegetation in a region that is known as a biome.

Terrestrial biomes are a self-regulating association characterized by specific plant formation; usually named for the predominant vegetation are called biomes. The ecologists recognized the following major terrestrial biomes of the world.

TROPICAL EVERGREEN RAINFORESTS BIOME

This biome is a narrow fluctuating belt of unsteady light, variable winds, low atmospheric pressure, and frequent small-scale disturbances. They are located near the equator (25 degrees north and 10 degrees south). The annual temperature range is 20-30 degrees Celsius, and it is always hot. Annual precipitation is 202 cm (103 inches) and is called optimum biomes because they provide optimum environmental conditions such as hot and humid climate for the better growth and development of plants and animals.
Their global position is almost found in amazon basin (south America), Congo basin (Africa) and the countries of the southeast Asia. Also cover the equatorial regions of Africa, Indonesia, Malabar coast and hilly northeast India, Madagascar and some parts of southeast Asian countries. The pacific coast of Ecuador, Peru, Colombia and east coast of central America and east indies from Sumatra to new Guana.
The world's largest biodiversity spot, as many as 3000 species found in a few kilometers. Tree is the most significant members constituting about 70 % of total plant species. Creepers(climbers) are the second most important floral species. Tree leaves are large and green so called evergreen forests. Epiphytes such as orchids, bromeliads, fern, mosses and lichens found about 90% in this biome. The canopy of the forest have three different layers based on tallness.
The number of large-sized animals is less, as the elephant of this biome is always much smaller in size. Some large sized mammals of this biome can move by pushing thickets of plants away e.g. chimpanzee, gorilla, bison, African elephant, leopard and pigs. Animals of this biome are less mobile because of plenty food have additional features to climb over the trees like claws, fingers, foes and adhesive pads.

TROPICAL (MONSOON) DECIDUOUS FORESTS BIOMES

These are found on the margins of tropical rainforest biome. Monsoon biomes are mostly deciduous adapted to a long dry season in the wet-dry tropical climate. The long rainy season alternates with a dry, rather cool season. Annual rainfall is 120-200cm. The average temperature of this biome is less than 18 degrees Celsius and almost variable.
They globally exist in the regions of India, Myanmar, Thailand, some parts of Indonesia, Malaysia, Vietnam, Laos, Cambodia, Philippines, Angola, Zambia, Zimbabwe, Tanzania, Nigeria, central America, west indies, parts of Brazil, Guyana and Venezuela.

The average height is 15-25 meters with no continuous canopy. The wood of these trees is mostly used for furniture, paneling, decking, lumbering and also valuable for cabinetry. Mostly open in nature, so light easily reaches the lower layers, so these layers are better developed than the tropical rain forest. Ony shrubs are evergreen in these deciduous forests. The trees have girth of stems, thick bark and hard xerophytic leaves. Somes of these trees have adaptation with dry season to produce waxes and gums. The important tree of this biome; teak, Sal, bamboo etc.
This biome has elephants, horses, hippos, rhinoceros, lions, wild buffalo and birds. Largest number of domesticated mammals because of the development of agriculture. The largest concentration of the world's human population exists in this biome.

TROPICAL SAVANNAH (TROPICAL WET AND DRY) BIOME

This biome is mostly grass with scattered trees. The latitudinal location is 15˚North to 25˚south.These are the transition zones between tropical rain forests, tropical deciduous forests and the drier, semi-arid tropical deserts. Temperature range is nearly 18˚C to 25˚C and the annual precipitation is 90-150 cm.
They global range is in African continent including Sudan, Ethiopia, Kenya, Somalia, Tanzania etc. other countries are India, Indonesia, South America and north coast of Australia.
It covers more than 40% of the earth's land. According to ecologists, savannah biome is the result of deforestation, frequent forest fires and overgrazing. This is the outcome of complex factors such as geo-climatic, socio-economic and human interactions.
Famous trees of this biome is baobab (in Sudan), palm, eucalyptus and calophylla (found in Australia). Common crops are millets, Sorghum, wheat, maize, fodder, pulses, oil seeds and peanuts.
Common mammals of this biome is Cheetah, lions, Zebra, Giraffe, wild-buffalo, Gazelle, Antelope (Bara Senga), Rhinoceros (Ganda), hippopotamuses and elephants.
Australian savannah is dominated by marsupials(kangaroo), deer, Guanaco (Indian mammals). Moreover, this savannah has many birds like doves, kingfishers, parakeets (small parrots), woodpeckers, parrots and Toucans (tropical American bird).
East African savannah is the richest interims of total population of animals. Shrubs and trees are xerophytic or drought resistant with distinct features e.g. small thick leaves, rough bark, and waxy leaf surface. African savannah is the richest in terms of primary productivity. East central African savannah primary productivity is about 900 grams per square meter.

SUBTROPICAL EVERGREEN BIOME

The mil-latitude broad-leaf and mixed deciduous and some evergreen species also called humid -climate. They have globally existed in eastern parts of USA, great lakes region, North America, North Chaina, North Korea, South Korea and Japan.
Eastern side of the biome have warm water currents e.g. Gulf stream of the coast of USA, Kuro-Shio along the east coast of Japan and China. Brazil currents along the east coast of South America, East Australian currents off the coast of Australia and Mozambique currents along the South-east coast of Africa.
Flora: red pines, hemlock, mixed and deciduous varieties of Oak, beech, hickory, maple, Elm, Chestnut. Broad-leaved forests are both deciduous and evergreen depending on the distribution of annual rainfall. These forests have valuable timber but altered mainly by deforestation, for example in the northern China for agricultural purposes.
warm-moist air blows into the continent from oceans. Hurricanes are a real threat to this climate; they can bring heavy rain, violent winds, high sea surges and are always subject to hurricanes in late summer or in autumn.

MEDITERRANEAN BIOME

With latitudinal position from 30˚ and up to 45˚ in both hemispheres. Globally this biome is found mainly around the Mediterranean Sea in Europe, Africa and Asia-minor (coastal turkey), central California, central Chile, Southern parts of south Africa, Tasmania and south-east and south-western coastal Australia.
flora: high altitude of the biome has beech, pine and pir. The tallest species of eucalyptus karri is main vegetation in Australia. The dominant shrubs have the ability to withstand hard summer droughts. The topmost canopy of vegetation is dominated by evergreen and deciduous oak.
Commercial crops are olives, figs, cork, citrus fruits, vegetables, flowers and nuts.
Fauna: deer, Guanaco (mostly found in Chile), Grizzly bear, lions, wolfs, rodents, rabbits, foxes, lizards, snakes, several types of birds, kites, falcons and hawks. The Australian Mediterranean biome is characterized by marsupials(kangaroos), numerous birds like honey eaters, whistlers, robins and quill.

TEMPERATE RAINFOREST BIOME

Temperate means moderate or mild. The regions have all four seasons with warm or hot summers and cool to cold winters, known for lush green middle and high latitudes. This region has rainfall between 150-500cm. This biome occurs only along the narrow margins of the pacific coast in north-west Africa. Have few species of trees. The tallest trees are found in this biome. The tallest tree is from 60 to 90 meters and the age is 1500 years old. Main species of the tallest tree are red wood (sequoia *sempervirens)*. Other trees of this biome are Douglas, fir, spruce, cedar and hemlock reduced occupying less than 10% of the original forest in Oregon and Washington states of America.

TEMPERATE DECIDUOUS FORESTS

Mid-latitude deciduous forest, in other words exist between equator and poles.
Global position: native to east-north America and west Europe. Tall and broad- leaf trees that have dense canopy in summer but shed their leaves completely in winters. Air masses from the tropics and poles meet here, which create variety.

1) **Temperate grass-land biomes**

The mid-latitude or temperate grasslands are natural biomes which are most modified by human activity. It lies in the interior parts of continent also called "breadbasket" region of the world because of grain and livestock production.
All over the world with different local/native names e.g. *prairies* in North America, *steppe* in Argentina and Uruguay, *veld* in South Africa and *Down*s in A Australia.
The flora of these regions are Bison(grass-eater), antelopes, dog and wolves etc.

DESERT BIOMES

Cover more than one by third (1/3) area of the world. Some desert plants called *ephemerals*, wait years for rainfall event for germination. Some xerophytic seeds open only when exposed to hard and harsh environment. Perennial desert plants have other distinct features to cope with the desert, such as long, deep taproots e.g. chaparral and maquis. The plants are succulence (i.e thick, fleshy water holding tissues such as cacti and saguaro), spreading root-system to maximize water availability, waxy coating and fine hairs on leaves to retard water loss, leafless conditions during dry periods, reflective surfaces to reduce leaf temperatures and tissues that have bad taste to discourage herbivores.
The deserts of the world are classified into two groups as follows:

HOT DESERT BIOME

Principally, the deserts are divided into tropical and subtropical due to the presence of dry air and low precipitation from subtropical high-pressure cells. True deserts are constantly dry and stable air of high-pressure systems from 8-12 months of the year. According to the definition of the desert that an area which receives annual rainfall less than 10 inches per year. The dryest place of the world is Atacama Desert of North Chile (a 30-year annual average rainfall of only 0.05cm) and annual precipitation is less than 20cm.

Few sub-tropical deserts along the seacoast are influenced by cold offshore ocean currents are Atacama (Chile), western Sahara, Namibia (Africa), Arizona (USA) and Great Victoria Desert (Australia). These deserts experience summer fog and mist needed by plants of the desert biome are cactus, creosote bush and acacia. In salt deposit areas, seep wood, geese wood and salt grass are common.

COLD DESERT BIOME

Occur at high altitude (mid-latitude or temperate) where seasonal shifting of subtropical high pressure is of some influence less than six (6) months of the year. Interior locations are dry because of their distance from moisture - source or their location in rain shadow areas on the lee side of the mountain regions such as Himalayas, Andes and Rockies.

These positioning produces the cold deserts of the great Basin of western north America, Patagonia, Ladakh (India), central Asia, Gobi (China and magnolia) and not western China. It is cold to moderate temperature(10-20cm) with light snowfall. Nighttime temperatures drop even in summer season below 10 and 15 degrees. The dry clear skies and sparse vegetation lead to high radiative heat loss resulting in cool evening and pleasant nights.

TAIGA(BOREAL) OR CONIFEROUS FOREST BIOMES

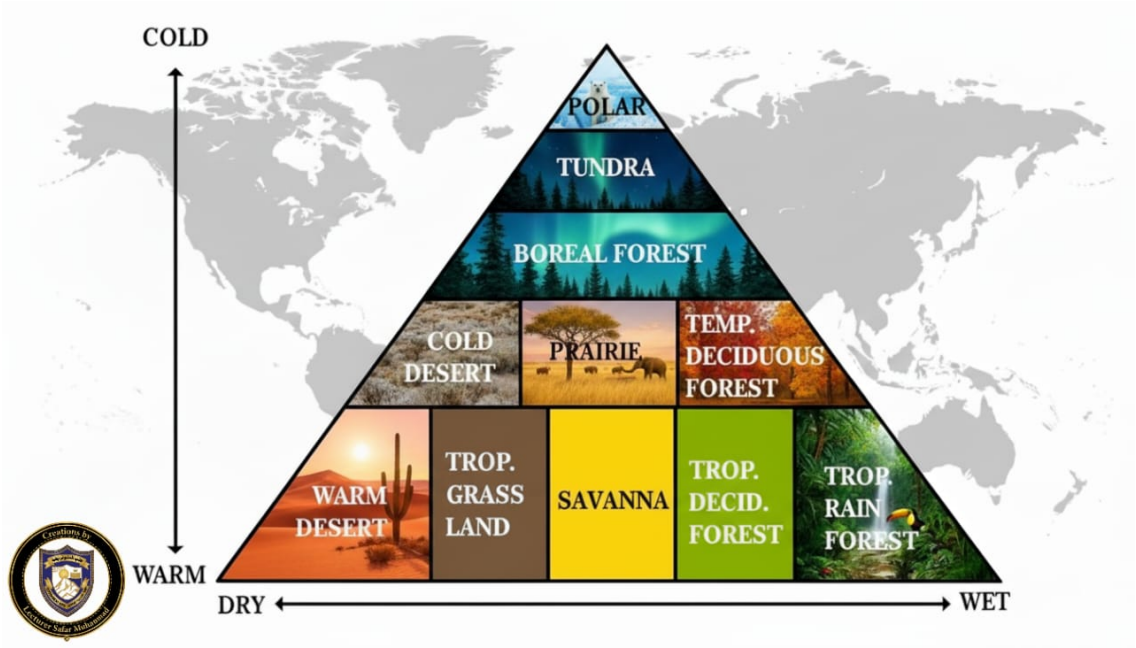
This biome is mostly confined to the northern hemisphere from Alaska to eastern coast of Canada, Scandinavian countries. The also the entire extent of the Eurasia from European Russia to Siberia. High altitudes of Himalayas, Andes, Rockies, Alps etc. are also covered with trees of this biome. This biome is characterized by extreme continentality.
The lowest recorded temperature of this biome is -69˚C in *Verkhoyansk* of Siberia in the northern hemisphere. Permafrost soil from five to seven months. Mean annual precipitation is 35-60 cm. Moscow with temperature -12 Celsius in January and 20˚C in July.
Main trees of this biome are pines, spruce, fir and larch. Some temperate deciduous trees are Alder, birch and poplar. Coniferous leaves are small, thick, leathery and needle-shaped so that they can control transpiration. The forests are economically important for lumbering and furniture marketing.

TUNDRA BIOME

This biome is in the northern most portion of the north America (Alaska, northern Canada), coastal strip of green land, arctic Iceland and Eurasia. Winters in this biome are long and cold, cool summers are however brief. Winters have intensely cold continental polar air masses and stable high-pressure anticyclone.
The growing season is of short duration and lasts only about 60 days and frost occurs anytime. Vegetation is fragile, treeless world and baren land, soils are properly developed characterized with permafrost.
Low, ground level herbaceous plants such as sedges, mosses, arctic meadow grass, snow lichen and some woody species like dwarf willow. The cryospheric conditions are not conductive for the growth of vegetation. Most plants' height is from 5 to 8 centimeters. Herbaceous plants include moss campions (silence acaulis), plants grow on ground are tussocks, some grow horizontally like mats or compact turf.
Low primary productivity because of low temperature, permafrost conditions, minimum sunlight and isolation. The harsh climate results in poor vegetation, dry areas produce little litter. Wet litter accumulates to form peat and swamps, and little nutrients reduce the vegetation productivity.
Reindeer, caribou, white bear, polar pox, muskox, stoats, wolves and rodents are common in this biome. Most animals of this biome have thick and dense insulating coats of fur or features around their bodies. So, they keep animals warm in winter. Polar bears are well-adopted to swimming with a winter-repellent coat and webbed feet. Migratory birds are waterfowl, ducks, swans, geese etc. insects are mosquitoes, midges and blacky in summers.

ALPINE TUNDRA OR HILAND BIOME

Any place in the world with altitude, similar to an arctic tundra, but can occur at lower latitudes. Same precipitation as arctic tundra i.e. 25centimeters.
Global position of this biome lies, Andes range near equator, the Himalayas, white mountains of California, the Rockies, the Alps and Mt. Kilimanjaro of equatorial Africa as well as mountains from middle east to Africa.



CHAPTER 8 CLIMATE CHANGE

Simply climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, but since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels (like coal, oil and gas), which produce heat-trapping gases. Burning fossil fuels generate greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures.

The main greenhouse gases that are causing climate change include carbon dioxide and methane. These come from using gasoline for driving a car or coal for heating a building, for example. Clearing land and cutting down forests can also release carbon dioxide. Agriculture, oil and gas operations are major sources of methane emissions. Energy, industry, transport, buildings, agriculture and land use are among the main sources causing greenhouse gases.

CONCEPT OF THE GREENHOUSE

The extremely important role that the atmosphere plays heating the earth's land-sea surface is known as "greenhouse effect". Earth's atmosphere traps some of the outgoing radiation which makes our planet habitable. If earth has no gases to form the atmosphere, it will have an average surface temperature below freezing. Clean air (having no pollutants) is largely transparent to incoming shortwave solar radiation and hence, transmits much of it to earth's surface, where it can be absorbed and then eventually reradiated skyward. Two atmospheric gases (water vapors and carbon dioxide) are meteorologically important because they absorb a significant portion of the long wave(infra-red) radiation emitted by earth's surface.

Water vapor strongly absorbs infra-red radiation in the range 4000 to 8000 nm (4-8 μm) while carbon dioxide in the range of 12000 to 16300 nm (12-16 μm). So, carbon dioxide and water vapors traps about 60% heat to habitable the planet. The radiation in the range from 8000 to 12000nm escape unabsorbed and this is known as atmospheric window.

As the earth's radiation heats these absorptive gases, the temperature of the atmosphere increases. The atmosphere in turn radiates some of this energy out to space, but more importantly, it radiates an equivalent amount back towards the earth's surface. Without these atmospheric gases, earth's average temperature would be -18℃ rather than the current temperature of 15℃. in fact the greenhouse gases are responsible for keeping our planet warm thus sustaining on earth.

If the greenhouse gases are very less or totally absented as on the surface of moon, all the absorbed temperature will be lost. In contrast Venus experiences extraordinary greenhouse warming, which is estimated to raise its surface temperature by 523℃, thus making the existence of life impossible there.

The earth's atmosphere absorbs some of the infrared radiation emitted by the surface, but a portion of this energy is radiated back to the surface and is responsible for keeping earth's surface 33℃ warmer than it would otherwise be.

Basic difference of greenhouse effect from global warming

Sometimes the greenhouse effect is considered as a global warming problem, however the greenhouse effect and global warming are different concepts. Without the greenhouse effect, the earth would be inhabitable. Scientists have mounting evidence that human activities (particularly the release of carbon dioxide into the atmosphere) are responsible for a rise in global temperature. Thus, humans are compounding the effects of an otherwise natural process (the greenhouse effect).

It is incorrect to equate the greenhouse phenomenon, which makes life possible, with global warming, which involves undesirable changes to our atmosphere and is caused mainly by human activities**.**

INTENSE GREENHOUSE GASES

In the natural conditions of the atmosphere, the average temperature is 15℃. the sun rays of different wavelength and frequency (see electromagnetic spectrum) reaching the earth's surface and absorbed in the ground, some amounts of these rays are emitted back to the atmosphere in the form of infrared rays (high wavelength with low frequency). These rays are trapped by the gases envelop around the earth called greenhouse gases.

The use of fossil fuels by human activities increases the amount of greenhouse gases and other pollutants in the atmosphere (in which we breathe), increases the temperature of the lowermost atmosphere. These gases are carbon dioxide, ozone, methane, nitrous oxide, chlorofluorocarbons (CFCS) and water vapors.

Due to industrial revolution and use of fossil fuels in automobiles and for domestic purposes, increases the amount of these gases in the troposphere, which trap more and more heat inside the blanket. This warming of the global atmosphere changes the weather patterns and climate on a large scale. It is measured that the world temperature increased 1 degree. Scientists argue that only 0.5-degree increase have catastrophic consequences.

According to Kyoto protocol, six gases were identified causing warming globally.

Carbon dioxide, methane, nitrous oxide, hydrofluoric carbons, per fluorocarbons, Sulphur hexafluoride. Sulphur hexafluoride (HF_6), methane (CH_4), and nitrous oxide(N_2O) have many times more global warming potential than carbon dioxide. But the highest amount in these global warming gases is carbon dioxide because fossil fuels have a high amount of carbon, which react plenty of oxygen forming CO_2.

$$C \text{ (carbon black)} + \tfrac{1}{2} O_2 \longrightarrow CO$$

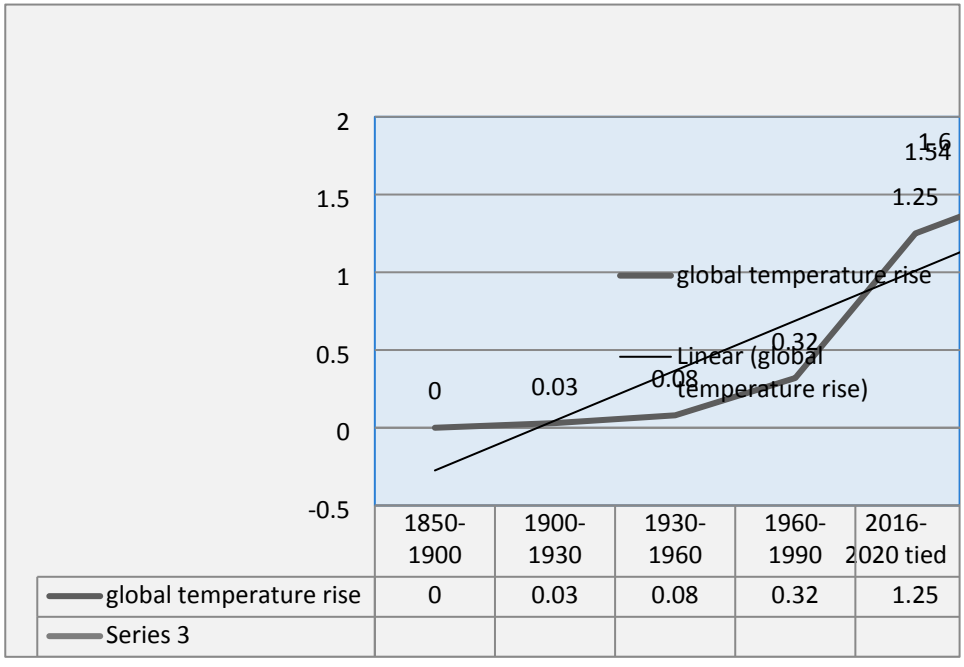
$$C \text{ (soot)} + O_2 \longrightarrow CO_2$$

It is estimated that the atmospheric carbon dioxide content has increased by 25% during the last two centuries. All the emissions of global warming gases, carbon dioxide account for

53% followed by methane, which is 17%, nitrous oxide is 12% and the other global warming gases are collectively 18%.

The fallowing graph shows the global temperature rise in the last 174 years because of the industrial revolution. Ten of the warmest years in this temperature record had also occurred during the last decade (2015-2024). According to NASA`s report, the 2024 was the warmest year, 1.47˚C warmer than the mid-19th century average. This exceeds the previous record set in 2023 by approximately 0.08˚C. Global average temperature is projected to rise about 1.5℃ by 2050 and 2-4 degrees Celsius by 2100. All analysis confirms that 2024 was the warmest year since modern record-keeping began in 1850. The past ten consecutive years have been the warmest ten years on record, with significant implications for climate change and global warming trends.

The period from 1850-1900 is sometime used as a reference period for measuring temperature changes. This is also taken as pre-industrial era with normal temperature or no temperature changes. The following graph shows the global average temperature rise trends as compared to the mid-19th century (1850-1900).



By the UN report and its data published in newspaper stated that “the rise in earth’s global average surface temperature, however, has already reached around 1.1˚C, higher than the pre-industrial average (1850-1900), and 2023 is already on track to be the worst year on record. Under the current level of mitigation actions, the peak temperature for 2100 is estimated in the range of 2.1- 2.8˚C.

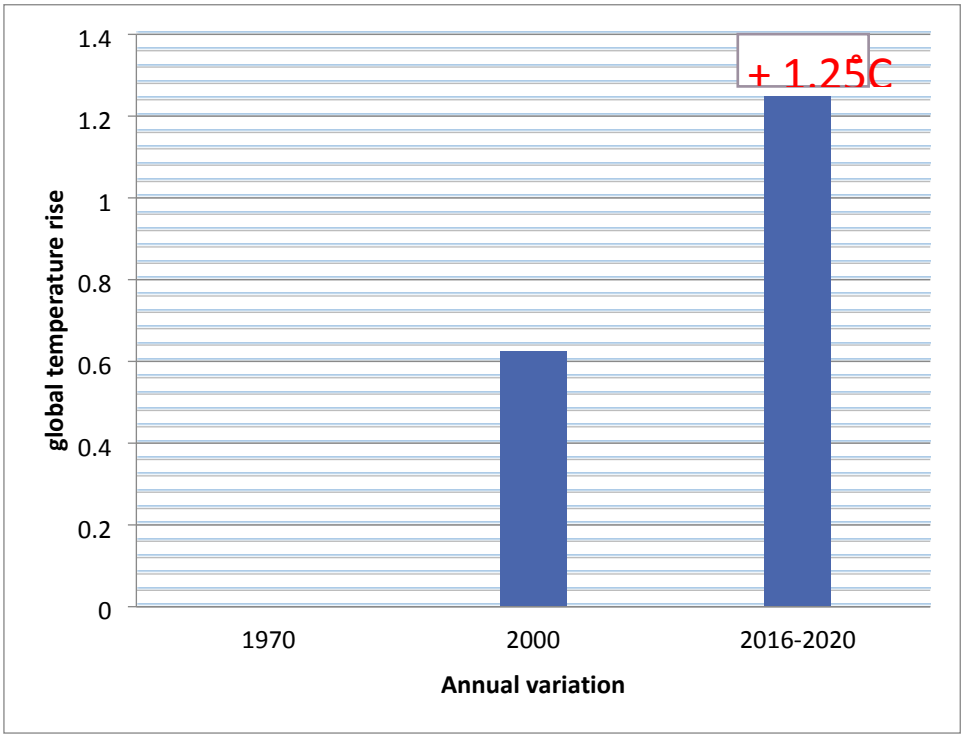
LONG TERM CLIMATIC CHANGES

Climate is the long-term average of a region's weather events. The Earth's climate is not static. Over billions of years of earth's existence, it has changed many times in response to natural causes like sunspot, ice age glaciation, etc.

"Climate change" means a change of climate which is attributed directly or indirectly to human activities that alters the composition of the global atmosphere, which in addition to natural climate variability observed over comparable time periods. However, when today people talk about 'climate change, they mean the changes in climate over the last 100 years which are caused predominantly by human activity.

The phrase 'climate change' represents a change in the long-term weather patterns. Climate change is not a change of weather in a particular day; it is the cumulative change of long-term weather patterns, for example, it's possible that a winter day in Jammu could be sunny and mild, but the average weather, the climate, tells us that Jammu's winters will mainly be cold and include snow and rain. The change in the pattern of Jammu's winters from the normal winter pattern represents an epitome of climate change. Climate change is the measurable effect of the continual warming trend. Climate change is usually measured in major shifts in temperature, rainfall, snow, and wind patterns lasting decades or more. Humans are creating climate change by burning large amounts of fossil fuels (coal, oil, natural gas), deforestation (when forests are cut down or burned, they can no longer store carbon, and the carbon is released into the atmosphere).

Following is the World Bank data of past fifty years. Industrialization was started on a small scale during the start of the twenty century, but the pollution cases were first time observed in 1970es. The recent tie of six years from 2016 to 2020 was the warmest temperature record compared to past data. 2020 was 0.6˚C warmer than the standard 1981-2010 reference period and around 1.25˚C above the pre-industrial period (1850-1900).



Source: Copernicus C3S/ECMWF. temperature variations compared to the pre-industrial period, 2020 ties 2016 was the hottest years record.

EFFECTS OF CLIMATE CHANGE

EFFECTS ON HUMANS' HEALTH

Warmer temperatures increase the spread of diseases, heat stress, and other health problems. Humans are severely affected by climate change. The rising temperatures can affect all aged people but mostly children's and old age people. The changing climate may increase the growth of microorganisms which can cause infectious diseases. The major air pollutants in photochemical reactions can cause serious pulmonary disorders, especially in urban areas. Global warming may cause insect borne diseases; the spread of malaria by mosquitoes and encephalitis by bacteria and viruses are the examples. The current heat stroke episodes in metropolitan cities are due to average change in global temperatures.

EFFECTS ON BIODIVERSITY

Rising temperatures and changing ecosystems lead to the extinction of many plant and animal species. The endangered world animal, the polar bear on arctic pole, is severely affected because of the melting of ice caps and ice sheets of the north ocean. pangolin in antarctica is also affected because they are adopted with low temperatures.
Warmer ocean surfaces also destroy microbes, on which many marine lives nourish e.g. tiny shrimps and zooplanktons. The crabeater seal would be just one of the animals affected by the reduction of zooplanktons.

Warming of tropical waters may kill the microscopic algae on which coral reefs depend for food so destroying coral reefs. Coral reefs are also highly sensitive to warming and they are home to biodiversity. Scientists argued that most coral reefs of tropical seas will be destroyed by global warming.
Higher temperatures are experienced two to three times by poles as compared to equator. The plants and trees which are cold loving will migrate north ward beyond tree lines and become extinct. Birds living in northern Siberia cannot migrate to southward in winters because of higher temperatures in tropical regions.

EFFECTS ON TROPICAL FORESTS

Rising temperatures and droughts can lead to increased tree mortality. The tropical forests may be more affected by soil water availability as water availability is the combine effect of rainfall and temperature. This can alter the composition of plant species, favoring some species over others. Changes in temperature and precipitation patterns can alter the structure of the forest, including the density and height of trees.

The altering environment of tropical forests can change the migration patterns of animals, potentially disrupting food webs. Although the net primary productivity may increase but standing biomass may not increase because of frequent pest outbreaks and frequent wildfires. Rising temperatures and changing precipitation patterns can lead to habitat loss for some species. Climate change can exacerbate existing threats to species, such as habitat loss and fragmentation, leading to increased extinction risk. Any degradation of tropical forests due to climate change will lead to any irreversible loss in biodiversity.

Changes in temperature and precipitation patterns may have many combined impacts as nutrients availability in soil and their cycling, fire frequency, severity, and extent, impacting forests and wildlife. These forests are also facing many disasters like hurricanes and tornadoes which can destroy them.

EFFECTS ON TEMPERATE FORESTS

These forests have least threats by climate change because they exist between polar and tropical regions. These forests have broad leaves and always have four seasons. Water availability changes in these regions, so forests may be lost in the response to increased summer droughts. Almost all temperate forests are locating in developing countries, which can reduce the impacts of climate change on their forests through different strategies like integrated fire, pest and diseases management and encourage reforestation.

EFFECTS ON BOREAL(TAIGA) FORESTS

Boreal are the forests locating in the northern hemisphere from midlatitudes up to tundra on arctic pole. These are coniferous forests and two by third (66.66%) of the global forest cover. They are always called the lungs of the earth; they provide almost also oxygen to living beings. They have needle evergreen leaves, and the snow can fall from leaves.

They are locating in low temperatures zones and are severely affected by climate change than any other forests. Because, when global temperature changes, the temperature gradient of poles and tropics reduces, on which the global winds and heat circulation depends. The low temperature adopted trees will migrate north ward and upslopes (high altitudes), which are called rising tree lines. These northern tree lines are slowly advancing into regions currently occupied by tundra and collapsing.

EFFECTS ON AGRICULTURE

High temperatures can change rainfall patterns in the form of floods and storms that can impact crop growth and productivity. On contrast in some areas heatwaves and droughts can also damage crops and disrupt agricultural production. The demand for irrigation could increase so that it will deplete the ground aquifers which are already overused.

Decreased crop yields can lead to food shortages and price increases. Changes in temperature and precipitation patterns can alter the timing of growing seasons, making it challenging for farmers to adapt. Rising temperatures can alter growing seasons, reduce crop yields, and change the distribution of crops.

Rising sea levels, soil degradation, and increased salinization can reduce the availability of arable land. Farmers may face increased risks due to climate-related shocks, such as crop failures and livestock deaths. Climate-related impacts can lead to significant economic losses for farmers, affecting their livelihoods and food security. In some cases, climate change can lead to migration and displacement of farming communities.

Environmental tipping points refer to the critical thresholds at which small changes in environmental conditions can lead to sudden, drastic and often irreversible changes in ecosystems, biodiversity and climate. The irreversible changes to world ecosystems, such as melting of arctic ice, die-off of coral reefs, amazon rain die-off, west Antarctic ice sheet collapse, thawing of permafrost.

EFFECTS ON GLOBAL WINDS PATTERNS

As the global temperature is changing, the tropics receive more heat as compared to temperate and polar regions. But polar regions are two to three times more sensitive than tropical regions. The temperature gradient between tropics and poles will reduce because of global average temperature rise. The winds that are generating over tropics due to high temperature and low pressure will shift to other parts of the world. The winds circulation in higher altitudes from tropics to poles and horizontal movement near ground from poles to tropics will be disturbed. So, the whole world’s weather will be disturbed, leading to climate crisis.

CONSEQENCES OF RISING MEAN GLOBAL TEMPERATURE

Here are some of the consequences of global warming: These consequences can have far-reaching and devastating effects on ecosystems, human health, and the economy. It's essential to take immediate action to reduce greenhouse gas emissions and mitigate the impacts of global warming.

1. SEA LEVEL RISE

A significant impact of human induced global warming is a rise in sea-level. As this occurs, coastal cities, wetlands and low-lying islands could be threatened with more frequent flooding, increased shoreline erosion and saltwater encroachment into coastal rivers and aquifers.

How is a warmer atmosphere related to a rise in sea level? One significant factor is thermal expansion. Higher air temperature warms the adjacent upper layers of ocean, which in turn causes the water to expand and sea-level to rise.

A second factor contributing to global sea-level rise is melting glaciers, with few exceptions; glaciers around the world have been retreating at an unprecedented rate over the past century. Some mountain glaciers have disappeared altogether.

A satellite study spanning twenty years showed that the mass of the Greenland and Antarctic ice sheets dropped an average of 475 gaga tons (a gaga ton is one billion metric tons) per year. That is enough water to raise sea level 1.5 millimeters per year. The loss of ice was not steady but occurred at an accelerating rate during the study period. During the Same span, mountain glaciers and ice caps lost an average of slightly more than 400 gaga tons per year.

Research indicates that sea-level has risen about 25 centimeters (cm) since 1870, with the rate of sea-level rise accelerating in recent years.

2. EXTREME WEATHER EVENTS

Extreme weather events are weather conditions that are significantly different from the average or usual weather patterns in a particular region. These events can have severe impacts on the environment, human health, and the economy. Some common types of extreme weather events include:

HEATWAVES

Prolonged periods of abnormally hot weather. These are always caused by persistent high-pressure systems which can lead to heat waves by trapping warm air and supporting cloud formation. Build-up areas can absorb and retain heat also called urban heat island effect, making cities feel hotter than surrounding areas.
Notable heat waves examples are 2021 North American heat wave with high temperatures(49.6˚C) in British Columbia and Canada. Pakistan 2024 heat wave primarily in southern Pakistan with temperatures reaching as high as 49˚C, resulted in over 568 deaths.
A European newspaper quoted “the WHO and IPCC have cautioned repeatedly of a sharp increase in the frequent and intensity of extreme weather events -extreme rainfall, heat waves, floodings and droughts. To top it all, the IPCC most recent report states that global temperatures would most likely go beyond 1.5˚C higher than pre-industrial times within the next 10 years.”

DROUGHTS

Extended periods of abnormally low rainfall. The United Nations Convention to Combat Desertification (UNCCD) released a report in December 2024 titled "The World Drought Atlas." This comprehensive report warns that by 2050, approximately 75% of the global population will face drought challenges.

Case study: rising average temperature induced droughts
The Sahel region in Africa become barren land because of prolonged droughts. Here Over the past few decades, increased temperatures, reduced rainfalls and unsustainable usage have dried up almost 90% of Lack Chad, which borders Chad, Niger, Nigeria and Cameroon. This area is now considered a global security hotspot, now considered for the environmental catastrophe.

THUNDERSTORMS

Severe weather conditions with strong winds, heavy rainfall, thunder and lightning lead to thunderstorms. Thunderstorms can be developed, when the sun heats the ground, it warms the air closest to the Earth's surface, As the warm air rises, it cools, and the water vapor in the air condenses into tiny water droplets. The condensed water droplets gather to form cumulus clouds. If the conditions are right, the cumulus clouds can grow into towering cumulonimbus clouds.

TORNADOES

Tornadoes are rotating columns of air that touch the ground and are characterized by high wind speeds and destructive power. Tornadoes can be formed when warm and moist air near the surface exists.
Above the warm air, there is typically a layer of cold and dry air. When there is a significant change in wind speed or direction with height, it creates an area of rotation. As the warm air rises, it cools, and the water vapor in the air condensed into tiny water droplets forming cumulus clouds. Within the thunderstorm, a rotating updraft known as a mesocyclone can form. If the conditions are right, the mesocyclone can touch the ground, becoming a tornado.

HURRICANES

A hurricane or cyclone is a rapidly rotating storm system with a low-pressure area, a closed low-level atmospheric circulation, strong winds, and a spiral arrangement of thunderstorms that produce heavy rain.
As humans add greenhouse gases to the atmosphere, the average surface temperature of the earth should increase. How much and how fast it may warm is a matter of debate. One consequence is that measurements show that the global average sea surface temperature has generally been increasing since 1900. Therefore, since tropical cyclones feed off warm ocean water, one could argue that the recent strong landfalling tropical cyclones directly results from global warming.

MITIGATION STRATEGIES FOR CLIMATE CHANGE

Reduction of GHG Emissions: world has needed to cut 43% greenhouse gases emissions since 2030, compared to 2019 levels, but emissions under the current mitigation target are projected to be only 2% below those levels (Mohan, 2023).By 2030 the global community must deliver exceptionally steep cuts in greenhouse-gas (GHG) emissions on the order of four-plus decades of progress compressed into a few years, if the 1.5°C pathway is to remain viable, and current national pledges leave a large and closing "emissions gap" that requires far stronger near-term action (UNEP, 2024). Limiting warming to safe levels needs rapid, deep, and sustained reductions across all sectors, complemented by scale-up of carbon removal where necessary, while avoiding lock-in of high-emitting infrastructure (IPCC, 2022). Energy-system analyses show that reaching net-zero energy sector CO_2 by mid-century requires immediate acceleration of energy efficiency, large and rapid deployment of wind, solar and other zero-carbon electricity, and an equally rapid decline in coal and oil use in power and transport (IEA, 2023). Collective ambition and implementation are insufficient and that a significant increase in both mitigation commitments and near-term action is essential to close the gap and reduce climate risks (UNFCCC, 2023). Global anthropogenic greenhouse-gas (GHG) emissions reached about 53.2 Gt CO_2-equivalent (Gt CO_2 eq), representing a 1.3 % increase compared with 2023. China, USA, India, EU 27, Russia and Indonesia are six top emitters represent 61.8% of global emissions. Since 1990, China`s emissions have surged more than four-fold and India`s have nearly tripled. In Stark contrast, EU27 has cut it`s emissions by nearly 35% in the same period compared to 1990, s level, providing that economic growth and decarbonization (JRC, 2025).

A significant positive trend identified across recent climate assessments is the steady decline in greenhouse gas (GHG) emissions intensity. From 2015 to 2024, global GHG intensity fell by approximately 2.1 percent annually, reflecting improvements in energy efficiency, cleaner technologies, and renewable energy adoption (JRC, 2025). The global economy expanded by 3.1 percent in 2024, energy-related CO_2 emissions increased by only 1.1 percent, signifying continued decoupling of economic growth from emission (International Energy Agency, 2025). Many industrialized and emerging economies are increasingly generating more economic output with fewer emissions, although it cautioned that the current pace of reduction remains insufficient to limit warming to 1.5 °C. Collectively, these reports suggest that while absolute emissions remain a challenge, declining emissions intensity marks a critical step toward sustainable low-carbon development (UNEP, 2024). All major economies are reducing their emissions intensity (GHG emissions per unit of GDP). In 2024, China`s intensity of GHG dropped by 4.0%, The US by 2.4% and India`s 2.4% compared to the previous year.

On global scale, there are countless strategies in the UN agreements. UN climate change mitigation agreements like the Paris Agreement: aim to reduce GHGs emissions through various mitigation strategies, including transitioning to renewable energy, promoting energy efficiency, and implementing policies that limit fossil fuel use. The Paris Agreement also emphasizes the need for countries to adapt, the impacts of climate change. The United

Nations environmental Programme (UNEP) is working with all attached departments such as international panel on climate change (IPCC) to develop strategies for climate change mitigation. Following are some most important and common strategies to be adopted globally for GHG, s reduction and climate change mitigation.

CARBON SEQUESTRATION AND CARBON SINKS

According to the United Nations environmental platforms working for climate mitigation, carbon sequestration is a crucial process for mitigating climate change, involving the removal and storage of carbon dioxide from the atmosphere. The UNFCCC recognizes that carbon sequestration, particularly through natural processes like those found in forests and soils, plays a vital role in reducing greenhouse gas emissions and achieving climate targets. The UNFCCC also emphasizes the importance of carbon capture, use, and storage (CCUS) as a key technology for achieving emission reduction goals.

The UN based environmental platforms highly encouraged the importance of protecting and restoring natural carbon sinks like forests, wetlands, and oceans, which naturally absorb carbon dioxide from the atmosphere. These ecosystems act as "carbon reservoirs" and "tools to sequester additional carbon," contributing significantly to mitigating carbon emissions. The IPCC under the UN Framework Convention on Climate Change (UNFCCC) recognizes carbon sequestration activities related to land use, land-use change, and forestry as part of countries obligations. This includes activities like afforestation, reforestation and improved agricultural practices.

Carbon capture, use and storage (CCUS) can play a significant role in mitigating carbon emissions in the future and is a key technology for the decarbonization of the energy sector in the long term. Its mitigation potential is estimated by the United Nations Environment Programme (UNEP) to range from 0.2 to 0.4 Gaga tons CO_2 equivalent by 2020 and could increase to reach a level capable of capturing 1.5 Gaga tons CO2 in 2030 and 6.3 Gaga tons CO_2 in 2050.

The UN recognizes Carbon Capture, Use, and Storage (CCUS) as a crucial technology for achieving the 2°C goal. UNEP estimates that CCUS could significantly reduce emissions by 2030 and 2050. The UN platforms emphasize the need to scale up carbon dioxide removal efforts to achieve the Sustainable Development Goals (SDGs) and reach universal emission reduction targets.

MICROORGANISMS OF FERTILE SOIL AS A CARBON SINK

Soil microorganism's act as a major sink for CO from ambient atmosphere.it has been demonstrated that 2.8kg of a soil sample remove 120ppm of CO from ambient air in three hours. Although soil sinks can take-up of atmospheric CO, still it exists in significant concentrations in the atmosphere, because the largest CO producing areas have the least amount of soil sinks available around them.

The UN Environment Programme highlights the potential of carbon sequestration in the soil through improved agricultural practices, which can increase soil organic matter,

enhance food production, and improve ecosystem services. The UN urges for increased protection of carbon sinks, including rainforests, peatlands, and other ecosystems that are at risk of becoming carbon sources due to climate change and land degradation.

POLLUTER PAY PRINCIPLE

The Polluter-Pays Principle (PPP) is a fundamental concept in environmental law and policy which refers that individuals, organizations and governments are responsible for pollution, environmental damages and required to restore the affected areas to its original state. This principle aims to ensure that polluters bear the costs of their actions, preventing, controlling and cleaning up the damage and encourages sustainable development practices globally. Polluter Pays Principle have the objectives to encourage polluters to consider the environmental costs of their actions and take steps to minimize harm and to adopt environmentally friendly practices and technologies.

The Polluter Pays Principle (PPP) was first introduced in 1972 by the Organization for Economic Cooperation and Development (OECD). The main idea of the principle is that each polluter must achieve an economically efficient level of production and polluter must not see only benefits of the activity but also the harm imposed on people and environment. In adopting a ‘polluter pay principle, the strategy was to make those who produce waste responsible for its recycling and disposal.

Although the PPP has helped to mitigate the damage being caused to the environment to some extent, most developing countries have not yet signed it as a main environmental policy guideline. The polluter pays principle faces significant challenges in developing countries for its effective implementation. Firstly, ambiguity persists regarding clear identification of the actual polluter or who should bear the cost? Secondly, the polluter may a poor household, informal sector firms, small and mid-size firms of formal sector and it is difficult to impose the liability on such polluter.

CARBON TRADING

Carbon trading is the name given to the exchange of emission permits. This exchange may take place within the economy or may take the form of international transaction.

• Two types of Carbon trading:

1. Emission trading and

2. Offset trading.

Emission trading/ cap-and-trade

Emission permit is also called carbon credit. For each country either developed or developing, the protocol has assigned a fixed amount of carbon emission in the agreement. This amount is the amount of emission which is to be reduced by the country concerned.

On the other hand, it implies that the country was permitted to emit the remaining amount. This emission allowance is one kind of carbon credit.

The total amount of allowance is then subdivided into certain units. The units are expressed in terms of carbon equivalent. Each unit gives the owner the right to emit one metric ton of carbon dioxide or other equivalent greenhouse gases.

Offset Trading/ Carbon Project/ baseline-and

Credit' trading:

Another type of carbon credit is to be earned by a country by investing some amount of money in such projects, known as carbon projects, which will emit lesser amount of green-house gas in the atmosphere.

Carbon offsets are credits for reductions in greenhouse gas emissions made at another location, such as wind farms and solar panels which create renewable energy and reduce the need for fossil-fuel powered energy. Carbon offsets are quantified and sold in metric tons of carbon dioxide equivalent (CO2 e). Buying one ton of carbon offset means there will be one less ton of carbon dioxide in the atmosphere than there would otherwise have been. Carbon offsetting is often the fastest way to achieve the deepest reductions within businesses, and it also often deliver added benefits at the project site, such as employment opportunities, community development programmers, training and education.

CARBON TAXING

Carbon tax is the potential alternative to the 'cap and trade' method used by the Kyoto protocol. This tax is based on the amount of carbon contained in fuel such as coal, etc. The aim of this tax is to cause less fossil fuel use and hopefully cause an incentive to use other sources of energy.

If the carbon tax was implemented, it would be gradual and start at a low amount and increase over time to allow better industry and technology to be developed. The primary reasons why a carbon tax could prove more beneficial than the 'cap and trade' system are as follows:

1. Predictability: The tax could help predict energy prices which might also help investments in energy efficiency and alternative fuels.

2. Implementation - a carbon tax could be put into use much more quickly compared to the legalities that go along with the 'cap and trade' method.

3. Understandable – the carbon tax is simpler to understand and may therefore be embraced more by everyday people.

4. Lack of Manipulation – special interest groups have less of a chance to manipulate a carbon tax because of its simplicity.

5. Rebates – like other forms of taxes, the carbon tax could be open for rebates to the public.

CONCEPT OF CARBON FOOTPRINTS

A carbon footprint is the total amount of greenhouse gases (GHGs) emitted directly or indirectly by an individual, organization, product, or service. It's usually measured in tons of carbon dioxide equivalent (tCO2e).

The concept of carbon footprint was developed in the late 1990s and early 2000s, in the context of climate change research. The UK's Carbon Trust organization popularized the term "carbon footprint" in a report titled "Carbon Footprint" and also the UK government introduced the Carbon Reduction Commitment (CRC) scheme, which required organizations to measure and reduce their carbon footprint. This is a new approach for understanding and addressing Climate Change." In 2001, the World Wildlife Fund (WWF) and the Carbon Trust launched a joint initiative to promote carbon foot printing. In the year2004, The International Organization for Standardization (ISO) published the first standard for carbon foot printing (ISO 14064). The Intergovernmental Panel on Climate Change (IPCC) also highlighted the importance of carbon footprints in its most updated document "sixth Assessment Report on climate change" in March 2023.

PAKISTAN'S STRATEGIES FOR CLIMATE CHANGE MITIGATION

Pakistan's per capita emissions of greenhouse gases today is one of the lowest in the world. Yet it ranks amongst the top ten countries most affected by climate change (Pakistan climate change act, 2017). Pakistan share of greenhouse gases emission is 0.93% and ranking in climate vulnerability index is 150(UNDP, 2025). During the last twenty years, the country now regularly suffers from the vagaries of climate change, including climate-induced phenomena such as floods, droughts, desertification, glacial melt, and sea-water intrusion. The recent 2022 floods left eight million Pakistanis displaced. Extreme climatic events have resulted in tragic loss of lives and colossal damage to the economy. indeed, they have significantly impeded our efforts to promote sustainable growth and development.

The Framework for implementation of the National Climate Change Policy for the period 2014-2030 serves to integrate climate-friendly policies into our national and economic planning. The Framework spells out appropriate adaptation actions as well as mitigation measures covering all sectors of the economy and ensuring economic prosperity of the people. Our blueprint of 2025 for a future-oriented and growth-centric road map for Pakistan, clearly recognizes global warming and climate change as priority areas for effective action by the Government.

Pakistan climate change policy report 2012, says that, Pakistan's greenhouse gases (GHG) emissions are low compared to international standards. In 2008 Pakistan's total GHG emissions were 310 million tons of CO2 equivalent. These comprised: CO2 54%; Methane (CH4) 36%; Nitrous Oxide (N2O) 9%; Carbon Monoxide (CO) 0.7%; and Non-Methane

Volatile Organic Compounds 0.3%. The energy sector is the single largest source of GHG emission in Pakistan; it accounts for nearly 51% of these emissions and is followed by the agriculture sector (39%), industrial processes (6%), land use, land use change and forestry accounts only (3%) emissions and waste (1%).

By the new climate change policy 2021, Pakistan's greenhouse gas (GHG) emissions per-capita are low compared to international standards. In 2017- 18 Pakistan's total GHG emissions were 490 million tons of CO2 equivalents. The Agriculture, Forestry & Land Use sector is the largest source of GHG emissions in Pakistan; it accounts for nearly 46% of these emissions and is followed by the energy sector (45%), industrial processes (5%), emissions and waste (4%).

According to the above data, the most important targets for mitigation efforts focused on reduction of GHG emissions are the energy and agriculture sectors.

CLIMATE MITIGATION AND RENEWABLE ENERGY PROJECTS

Pakistan has launched several climate mitigation projects to address the impacts of climate change. Some of the notable projects include:

Ten Billion Trees Tsunami Programme: This project aims to plant ten billion trees across Pakistan to combat climate change.

Climate Resilient Urban Human Settlements Unit: This project focuses on making urban human settlements more resilient to climate change.

Capacity Building on Water Quality Monitoring and SDG 6: This project aims to improve water quality monitoring and reporting in Pakistan.

Climate Promise - II: This project supports the government in achieving its Nationally Determined Contributions (NDCs) and mobilizing resources for effective implementation.

Strengthening Climate Adaptation and Resilience (SAR): This project supports the Pakistani government in adapting to climate change, with a focus on protecting vulnerable groups.

Recharge Pakistan: Building Pakistan's Resilience to Climate Change through Ecosystem-Based Adaptation for Integrated Flood Risk Management: This project aims to build Pakistan's climate resilience and water security through cost-effective ecosystem-based adaptation.

Wind Energy projects

Pakistan has considerable potential for using wind energy in the coastal belt of Sindh and Baluchistan. The Government of Pakistan has developed a wind power energy corridor along the southern coastal regions of Sindh and Baluchistan. Currently, 36 private wind projects are operating, producing approximately 1845MW.

Gharo-jhimpir Wind Power corridor is a significant wind energy resource area in Pakistan, locating in district Thatta Sindh, stretching 60 km along the coastline of Thatta and Badin. This corridor has an estimated wind power generation capacity of 43,000 MW.

Solar panels projects

Pakistan has an average of nine and a half hours of sunlight daily. Solar power entered Pakistan's energy mix in 2013 after the government introduced a set of support policies to foster renewable energy development. According to the Private Power & Infrastructure Board of the Ministry of Energy, seven solar projects of 530 MW are operational and supplying electricity to the national grid.Punjab government announced the establishment of Quaid-e-Azam Solar Park over an area of 5,000 acres in the Cholistan Development Authority in Bahawalpur.

CHAPTER 9 ENVIRONMENTAL POLICIES

KEY DIFFERENCE OF ENVIRONMENTAL CONFERENCE, CONVENTION AND PROTOCOL

Conference: The conference is a meeting of world leaders for negotiations on a general issue. In other words, there are many issues to be discussed in a conference meeting. In a conference meeting every representative of a country can attained the meeting.

Convention: Meeting of world leaders for a specified issue. An expert about the issue from a country can attend the meeting.

Protocol: The major distinction between the Protocol and the Convention is that the Convention encouraged countries to stabilize the issue while protocols have proper agreements, ratification and signatures. In other words, the Protocol commits them to do so.

Accession: Accession in environmental policy refers to the process where a country agrees to be bound by an international environmental treaty or agreement that it did not originally sign. This typically involves the country formally depositing an instrument of accession, signaling its consent to be bound by the treaty's terms.

Succession: Succession in environmental policy occurs when a country takes over the rights and obligations of a predecessor state, often due to changes in territorial boundaries or state sovereignty. This can happen in cases of state dissolution, merger, or secession. The successor state may assume the environmental treaty obligations of the predecessor state.

STOCKHOLM CONFERENCE OR UNCHE

The world first conference called united nation conference on human environment (UNCHE), held in Stockholm, Sweden from June 5-16, 1972. Almost 113 nations attended the conference. The conference meeting concluded on 26 principles. The extract of principles is to adopt the technology for the sustainable use of the natural environment and their resources and protect them from pollution.

OUTCOMES OF UNCHE

- 5TH June was declared as world environment day.
- The United nation environmental Programme (UNEP) was founded.
- Other environmental laws were adopted.

Pakistan attended the conference and added the word environment to the current 1973 constitution. The country also prepares environmental ordinance (1983). Pakistan concurrent legislative list item number 24 is about environment law. Environmental protection councils or agencies (EPAs) were also developed under ordinance in 1983.

EARTH SUMMIT OR UNCED

The United Nations sponsored Earth Summit, also known as united nation conference on environment development (UNCED) was held in Rio de Janeiro in 1992 from 3rd to 14th June. In this summit, leaders of 100 nations, over 10,000 delegates from over 160 countries, are nearly 9000 journalists participated. The focus of the conference was the agenda 21, the problems of 21st Century and the treaties, biodiversity and climatic change. The summit ended with the declaration of 27 principles which came to be known as Agenda 21 (the agenda for 21st century) based on the Stockholm conference.

Five Earth Summit agreements

Rio itself was not a binding document, but some binding and non-binding documents under Rio are as following:

1. Climate Change Framework: This legally binding agreement is a first-ever attempt to evaluate and address global warming on an international scale. This was signed in 1992 by 154 nations including Canada and USA.

2. Biological Diversity: This legally binding agreement is the first international attempt to protect the Earth's biodiversity. It provides more equitable rights among nations in biotechnology and genetic wealth of tropical ecosystems. Out of 161 signatories, the United States, Vietnam, Singapore and Kiribati (a Pacific Island nation) refused to sign the original treaty.

Non-binding documents of Rio conference

3. Management, Conservation, and Sustainable Development of all Types of Forests: This non-binding agreement guides world forestry practices toward a more sustainable future of forest yields and diversity.

4. The Earth Charter: This is a non-binding statement of 27 environmental and economic principles. They establish an ethical basis for a sustainable human–earth relationship. An important emphasis is the inclusion of environmental costs in economic assessments. Improvisation and utilization of air, soil, water and ecosystems sometimes is mistaken for progress. The environment is not an inexhaustible mine of resources to be tapped indefinitely. In terms of natural resources, the air, water, timber, fisheries, petroleum are limited to be deplete with time.

5. Agenda 21 (Sustainable Development): This non-binding action Programme is an 800–page guide for all nations into the 21st Century. The idea of 'sustainable development' as proposed in a business proposal for sustainable growth, is examined in Agenda 21. Agenda 21 covers many key topics: energy conservation and efficiency to reduce consumption and related pollution, climate change, stratospheric ozone depletion, trans-boundary air-pollution, ocean and water resource protection; soil losses, increasing desertification, deforestation, regulations for safely handling radioactive waste and disposal, hazardous chemicals exports for disposal in developing countries, disparities of wealth and the plague of poverty. Agenda 21 also discusses the difficult question of financing sustainable development. Developing countries are asking the developed nations to spend 0.7% of their

gross domestic product – about $125 billion per year – to assist them in implementing the Earth Charter and Agenda 21.

CONVENTION ON BIODIVERSITY

Convention on biological diversity is a legally binding convention which aims, the "conservation of biological". This is the common concern of humankind and is an integral part of the development process. The agreement covers all ecosystems, species and genetic resources.

KEY OBJECTIVES OF THE CONVENTION

- The conservation of biodiversity
- Sustainable use of the biological resources
- Fair and equitable sharing of benefits arising from the commercial and other utilization of genetic resources.

BASIC PROVISIONS

i. **National biodiversity strategies and action plans:** countries are encouraged to develop and implement national plans for the conservation and sustainable use of biodiversity.

ii. **Access and benefits sharing** countries have sovereign rights over their genetic resources and access to these resources is subject to prior informed consent and mutually agreed terms.

iii. **Protected areas:** establishing protected areas to conserve ecosystems and species.

Global impact and challenges

The CBD has been ratified by almost all countries worldwide and has contributed significantly to biodiversity conservation efforts. However, many challenges persist, including habitat loss, fragmentation, climate change and invasive species.

RECENT DEVELOPMENTS

- **Kunming-Montreal global biodiversity framework:** this is an international agreement aimed at conserving and sustainably using biodiversity worldwide. It includes twenty-three (23) action-oriented global targets for 2030. The decade of ecological restoration (2021-30) by COP 16 on conservation of biological diversity is a complement of it, which aims to protect 30% of terrestrial and marine biological diversity and promote sustainable use of these resources.
- **Cali fund:** established to ensure fair and equitable sharing of benefits from digital sequence information (DSI) on genetic resources.
- **Synthetic biology:** a thematic action plan has been introduced to help countries assess and apply synthetic biological technologies while safeguarding biodiversity.

CARTAGENA PROTOCOL ON BIOSAFETY TO THE CONVENTION OF BIOLOGICAL DIVERSITY

The Cartagena protocol on biosafety is an international agreement under the convention on biological diversity (CBD). It was adopted on January 29,2000, in Cartagena, Colombia, and came into force on September 11, 2003. Biosafety refers to the need to protect human health and the environment from the possible adverse effects of the products of modern biotechnology.

OBJECTIVE OF THE PROTOCOL

The main objective is to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.

This protocol is the agreement to the Convention on Biological Diversity. The Protocol establishes procedures for regulating the import and export of LMOs (living modified organisms) from one country to another. This also requires Parties of the CBD to ensure that LMOs being shipped from one country to another are handled, packaged and transported in a safe manner. The shipments must be accompanied by documentation that clearly identifies the LMOs, specifies any requirements for safe handling, storage, transport and use and provides contact details for further information. There are two main sets of procedures, one for LMOs intended for direct introduction into the environment, known as the advance informed agreement (AIA) procedure, and another for LMOs intended for direct use as food or feed, or for processing.

ADVANCE INFORMED AGREEMENT

Under the advance informed agreement procedure, a country intending to export an LMO for intentional release into the environment must notify in writing the Party of import before the first proposed export takes place. The Party of import must acknowledge receipt of the notification within 90 days and must communicate its decision on whether or not to import the LMO within 270 days.

Parties are required to ensure that their decisions are based on a risk assessment of the LMO, which must be carried out in a scientifically sound and transparent manner. Once a Party takes a decision on the LMO, it is required to communicate the decision as well as a summary of the risk assessment to a central information system, the Biosafety Clearing house (BCH is an online platform for sharing information about LMOs, national regulations and decisions). Under the procedure for LMOs- food or feed, or for processing, Parties that decide to approve and place such LMOs on the market are required to make their decision and relevant information, including the risk assessment reports, publicly available through the BCH.

BASEL CONVENTION ON TRAN'S BOUNDARY MOVEMENT OF HAZARDOUS WASTE

The Basel Convention on the Control of Trans boundary Movements of Hazardous Wastes and their Disposal was adopted on 22 March 1989 by the Conference of Plenipotentiaries in Basel, Switzerland, in response to a public outcry following the discovery, in the 1980s, in Africa and other parts of the developing world of deposits of toxic wastes imported from abroad. Objective To protect human health and the environment against the adverse effects of hazardous waste. Its scope of application covers a wide range of wastes defined as "hazardous waste based on their origin and/or composition and their characteristics, as well as two types of wastes defined as "other wastes" - household waste and incinerator ash.

PRINCIPLE AIMS:

• The reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous wastes, wherever the place of disposal.

• The restrictions over the trans-boundary movements of hazardous wastes except where it is perceived to be in accordance with the principles of environmentally sound management.

• A regulatory system applying to cases where trans-boundary movements are permissible.

WASTE UNDER THE BASEL CONVENTION

Wastes are substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

Annex-1 lists those wastes that are classified as hazardous and subject to the control procedures under the Convention. Two groups; one of that is Sources e.g. Pharmaceutical, hospital waste, industrial waste etc., and the other one is elements e.g. Cd, Hg, Pb, acids, bases etc.

Annex-2 of the Convention identifies those wastes that require special consideration; Consists of different sectors as household waste and its characteristics, incinerated wastes of hospitals. Other Examples of wastes regulated by the Basel Convention are as following

• Biomedical and healthcare waste

• Used oils

• Used lead acid batteries

• Persistent Organic Pollutant wastes (POPs waste)

• Thousands of chemical wastes generated by industries and other consumers

Annex-3. List of hazardous wastes e.g. Explosives, poisonous, toxic, infectious, corrosive effect and ecological cause.

Annex-4 pollution control and disposal methods

Annex-5. Information to be provided by notification and movement of documents

Annex-6. Arbitration or negotiation and sorting out waste problems

General obligations can be studied ln the official document.

UNITED NATION FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The United Nations sponsored Earth Summit, also known as united nation conference on environment and development (UNCED) was held in Rio de Janeiro in 1992 from 3rd to 14th June with a multilateral agendas but the key objective was the climate change. UNFCCC" is also the name of the Secretariat charged with supporting the operation of the convention, with offices on the UN Campus in Bonn, Germany. In 2022, the UNFCCC had198 Parties.

Countries joined UNFCCC to consider what they could do to limit average global temperature rise leading to climate change, and to cope with whatever impacts and consequences. The united nation convention on climate change is a framework convention. It calls its member states and signatories for the conferences of parties (COP) annually. Every year, different issues are growing in the context of climate change. All subsequent multilateral negotiations on different aspects of climate change, including both adaptation and mitigation, are being held based on the principles and objectives set out by the UNFCCC. They should also report on steps for returning individually or jointly to their 1990s greenhouse gas emission levels.

SECRETARIAT AND OFFICES

"UNFCCC" is also the name of the Secretariat charged with supporting the operation of the convention, with offices on the UN Campus in Bonn, Germany. Offices were formerly located in Haus Carstanjen and in a building on the UN Campus known as Langer Eugen. The UNFCCC secretariat supports all institutions involved in international climate change negotiations, particularly the Conference of the Parties (COP), the subsidiary bodies (which advise the COP), and the COP Bureau (which deals mainly with procedural and organizational issues arising from the COP and has technical functions).

The secretariat is established under Article 8 of the Convention and headed by the Executive Secretary. The secretariat, augmented through the parallel efforts of the Intergovernmental Panel on Climate Change (IPCC), aims to gain consensus through meetings and the discussion of various strategies. Since the signing of the UNFCCC treaty, Conferences of the Parties (COPs) have discussed how to achieve the treaty's aims.

KYOTO PROTOCOL (COP-3)

The world realized in 1995 that emission reductions provisions in the Convention on climate change were inadequate. They launched negotiations to strengthen the global response to climate change. Two years later, they adopted the Kyoto Protocol.
The Kyoto Protocol was adopted in Kyoto, Japan, on 11December 1997. Due to a complex ratification process, it entered into force on 16 February 2005 in COP-3. The Kyoto Protocol is what "operationalizes" UNFCCC. It commits industrialized countries to stabilize greenhouse gas emissions based on the principles of the Convention. Kyoto Protocol is a voluntary treaty, till date signed by 192 countries including the European Union, Japan and Canada.

According to this Protocol, the developed industrialized countries are required to reduce emissions of greenhouse gases by an average of 5.2 percent below 1990 levels till 2012.The Intergovernmental Panel on Climatic Change (IPCC) has predicted an average global rise in temperature of Earth from 1.4oC to 5.8oC between 1990 and 2100. If the protocol was successfully implemented, it will reduce the global temperature by somewhere 0.02^{o}C and 0.28^{o}C by the year 2050.

The following seven greenhouse gases (listed in Annexure A of the protocol) were identified in the Kyoto Protocol which causes global warming responsible for climate change: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), nitrogen trifluoride (NF3).

Targets of the Kyoto Protocol

The binding emission reduction target for 37 industrialized countries and the European community in its first commitment period. It only binds developed countries because it recognizes that they are largely responsible for the current high levels of GHG emissions in the atmosphere, which are the result of more than 150 years of industrial activity. KP also places a heavier burden on developed nations under its central principle: that of "common but differentiated responsibility". Overall, these targets add up to an average five percent emissions reduction compared to 1990 levels over the five-year period 2008 to 2012.

KYOTO PROTOCOL ADMINISTRATION SYSTEM

1. Reporting and verification procedures.
2. Flexible market-based mechanisms.
3. A compliance system.

So, two things make KP tick.

1. EMISSIONS REDUCTION COMMITMENTS

I. The first was binding emissions reduction commitments for developed countries of the COP; this meant the space to Pollute was limited.
II. Greenhouse gas emissions, most prevalently carbon dioxide, became a new and major commodity.

2. FLEXIBLE MARKET MECHANISMS

The flexible market mechanisms of the KP, based on the trade of emissions permits.KP countries bound to targets, must meet them largely through domestic action— that is, to reduce their emissions onshore. They can meet their targets through three "market-based mechanisms" that ideally encourage GHG abatement. To start where it is most cost-effective--for example, in the developing world. Quite simply, it does not matter where emissions are reduced, if they are removed from the earth's atmosphere.

The Kyoto Flexible Market Protocol mechanisms are as follows.

• Joint Implementation (JI)

• The Clean Development Mechanism (CDM)

• Emission Trading (discussed in above chapter)

JOINT IMPLEMENTATION:

A developed country (from annex B in original document) starts an emission reduction project or an alternative (renewable) project with another developed country to meet its Kyoto commitments and targets by earning emission reduction units (ERUs). ERU issued from 2008, are emission reduction units (ERUs) also called carbon credit is the reduction in carbon emissions of one ton (1000kg) carbon or CO2 or any other gas equivalent to one ton carbon.

Joint implementation offers Parties a flexible and Cost-efficient means of fulfilling a part of their Kyoto Commitments, while the host Party benefits from foreign investment and technology transfer. Projects starting from the year 2000 may be eligible as JI projects,

CLEAN DEVELOPMENT MECHANISM:

When a developed country launches emission-reduction project in developing countries to meet the emission- reduction or limitation commitments under Kyoto protocol. It is the first global environmental investment and credit scheme providing standardized emissions and offset instruments. Such projects can earn saleable certified emission reduction (CER) credits.

NON-COMPLIANCE OF KYOTO AND PENALTIES

In international and national laws and policies, if a member has not to comply with commitments, that member is fined by some charges called penalties. KP penalties are as follows:

• If a country does not meet the requirements for measurements and reporting said country loses the privilege of gaining credit through joint implementation

projects.

• If a country goes above its emissions cap and does not try to make up the difference through any of the mechanisms available, then said country must make up the difference plus an additional thirty percent during the next period.

• The country could also be banned from participating in the ‘cap and trade’ program.

The objectives of Kyoto mechanisms:

• Its objective is to facilitate, promote and enforce compliance with the commitments under the Protocol.

• Stimulate sustainable development through technology transfer and investment.

• Help countries with Kyoto commitments to meet their targets by reducing emissions or removing carbon from the atmosphere in other countries in a cost-effective way.

• Encourage the private sector and developing countries to contribute to emission reduction efforts.

DUHA AGREEMENT (2012) COP-18 EXTENDED KYOTO

The Paris Agreement is a landmark agreement, but its success depends on countries' collective efforts to meet their commitments and address the urgent threat of climate change. Doha Amendment (2012) Extended the Kyoto Protocol for a second commitment period (2013-2020) of eight years, with new emission reduction targets for developed countries. Increased ambition with more countries participating, expanded scope to include more greenhouse gases.

Kyoto Protocol, the agreement spraining (2005-2020)**,** Set binding emission reduction targets for developed countries, but had limitations, such as Excluded developing countries from emission reduction targets, having a narrow scope and only focusing mainly on CO2 emissions. Kyoto protocol also having a low level of ambition, with limited emission reductions.

PARIS AGREEMENT (2015) COP- 21: REPLACE THE KYOTO PROTOCOL

The Paris Agreement is an international accord aimed at mitigating climate change. It was adopted in 2015 and entered into force in 2016. The treaty covers climate change mitigation, adaptation, and finance. One hundred and ninety-seven (197) parties have joined the Paris agreement. This includes 194 states plus the European union. out of these, 195 have ratified. Of the three UNFCCC member states which have not ratified the agreement, the only major emitter is USA. The United States withdrew from the agreement in 2020 but rejoined in 2021. Iran is the second major emitter, which is signatory, but had not ratify the agreement due to international sanctions, which limit its access to green technologies, foreign investments, and climate finance.

The Paris agreement has a broader scope, covering all countries and all greenhouse gases. Having more ambitious goals, limiting global warming to well below 2°C and pursuing 1.5°C. To stay below 1.5 °C of global warming, emissions need to be cut by roughly 50% by 2030. This figure considers each country's documented pledges. adopted nationally determined contributions (NDCs). Countries submitted plans to reduce greenhouse gases emissions. The agreement provides flexibility and cooperation for each member country. The Doha Amendment bridged the gap between the Kyoto Protocol and the Paris

Agreement, allowing countries to meet their Kyoto commitments, while transitioning to the Paris Agreement and Build momentum for the Paris Agreement.

The Paris Agreement replaced the Kyoto Protocol as the primary international climate agreement, offering a more comprehensive and flexible framework for addressing climate change. A good financing system that the Developed countries aim to mobilize $100 billion annually for climate action in developing countries.

NATIONALLY DETERMINED CONTRIBUTIONS

At the 19th session of the Conference of the Parties in Warsaw in 2013, the UNFCCC created a mechanism for *Intended Nationally Determined Contributions (INDCs)* to be submitted in the run up to the 21st session of the Conference of the Parties in Paris (COP21) in 2015. Countries were given freedom and flexibility to ensure that these climate change mitigation and adaptation plans were nationally appropriate. This flexibility, especially regarding the types of actions to be undertaken, allowed for developing countries to tailor their plans to their specific adaptation and mitigation needs, as well as towards other needs. In the aftermath of COP21, these INDCs became Nationally Determined Contributions (NDCs) as each country ratified the Paris Agreement, unless a new NDC was submitted to the UNFCCC at the same time. The 22nd session of the Conference of the Parties (COP22) in Marrakesh focused on these Nationally Determined Contributions and their implementation, after the Paris Agreement entered into force on 4 November 2016.

The following are some most recent conferences which are carried by COP.

MARRAKECH CLIMATE CHANGE CONFERENCE-COP22,2016

For the successful implementation of the Paris agreement, UNFCCC launched a better finance system.IN Marrakech conference, the SBSTA began considering how to account for public finance. The **global stock-take** discussed by parties that how to structure the format, inputs, timeline and output and its linkage to the other elements of the Paris architecture.

One of the most common items of this conference was "**Orphans issues**." This was referenced in the Paris but not assigned for further consideration. These include whether to establish common timeframes for NDCs and any rules around the adjustment by parties of their NDCs. Also, the development of a new collective finance goal beyond 2025.

The Paris agreement encourages parties to prepare and submit "long-term low greenhouse gas emission development strategies." Outlining the kinds of actions needed to achieve much deeper emission reductions. In Marrakech, Canada, Germany, Mexico and the United States become the first countries to submit what have come to be known as **mid-century strategies.** A new initiative called 2050 pathway platform was launched.

The developed countries make a roadmap that how they foresee meeting the goal of mobilizing $100 billion a year in public and private finance for developing countries and a world bank finance for the middle east North Africa to $ 1.5 billion by 2020, for successful implementation of Paris agreement. In Marrakech, the UNFCCC committee on finance

released its second biennial assessment, showing that the total global finance increased 15% in 2013-14.

BONN CLIMATE CHANGE CONFERENCE-COP23,2017

Fiji is the first small-island state to host the UNFCCC COP-23 in Bonn, Germany in November 2017.key outcomes at the UN climate talks in Bonn are as following

i. **Powering past coal alliance**

Launched in COP23 in Bonn led by UK and Canada. It has more than thirty (30) member states aimed at accelerating clean growth and achieving the rapid phase-out of traditional coal. Alliance declares that "the coal phase-out is required in OECD and EU27 by 2030 and no later than by 2050 in the rest of the world" to meet the Paris agreement. They just restrict the signatories but have no binding shape.

ii. **Gende action plan**

Highlighting the role of women in climate action and promotes gender equality of sustainable development goals.

iii. **Local communities and indigenous people's platform**

Aim to support the exchange of experience and sharing of best practices on mitigation and adaptation.

iv. **Ocean pathway partnership**

Tow strategies were adopted for the best implementation of Paris agreement by 2020. First was, increasing the role of ocean considerations in the UNFCCC process and second was, increasing action in priority areas impacted or impacting by the ocean and climate change.

v. **Talanoa dialogue**

Talanoa dialogue is a process designed to help countries implement and enhance their nationally determined contributions by 2020. The process of Talanoa involves the sharing of ideas, skills and experience through storytelling.

vi. **Insu resilience global partnership**

This is the global partnership for climate and disaster risk finance and insurance solutions.it brings together G20 countries in partnership with the V20 nations. The V20 is a group almost 68 countries including small islands that are highly vulnerable to the impacts of climate change.

Its vision is to strengthen the resilience of developing countries and to protect the lives of poor and vulnerable people from the impacts of disasters. It also launched the disaster risk finance system for poor and vulnerable people of developing countries benefiting direct and indirect insurance by up to 400 million by 2020.

COP-29 (2024)

positive outcomes

1. Tripling Climate Finance for Developing Countries-: A major achievement of COP29 was the agreement to triple climate finance to developing countries from the previous target of USD 100 billion annually to USD 300 billion by 2035.

2. Establishment of Carbon Market Mechanisms- COP29 successfully finalized agreements on the carbon market mechanisms outlined in Article 6 of the Paris Agreement, which had been unresolved for nearly a decade. This includes provisions for both bilateral carbon trading and a global crediting mechanism.

3. Focus on National Adaptation Plans (NAPs)- A support program for implementing NAPs has been established at COP 29 to address climate adaptation for least developed countries (LDCs).

4. Commitment to Transparent Climate Reporting- COP29 has reinforced the importance of transparent reporting on climate finance and adaptation efforts. Biennial Transparency Reports (BTRs) were submitted by 13 countries under the Enhanced Transparency Framework.

SHORTCOMINGS OF COP 29

1. Inadequate Financing- The finance commitment of developed countries to provide $300 billion annually by 2035, is ‘too little, too distant ‘when compared to the estimated $1.3 trillion needed each year by the developing countries.

2. Overreliance on Loans Instead of Grants- The financial package agreed upon is being criticized for being heavily reliant on loans rather than grants. This approach of sanctioning loans instead of providing grants could exacerbate the debt burdens of developing nations already struggling with economic challenges.

3. Failure to Address Fossil Fuel Phase-Out- Transitioning away from fossil fuels’ that was hailed as a historic breakthrough in the final decision of COP 28 in Dubai was not repeated in the mitigation outcome in COP 29.

4. Unmet Emission Goals- COP 29 saw insufficient pledges to meet the 1.5°C target. According to IPCC global emissions have been rising in 2023.

5. Choice of Host Nation Concerns- The choice of Azerbaijan (Oil-rich economy and authoritarian governance) as the host nation has been criticized for contradicting the goals of a climate conference aimed at reducing fossil fuel dependence.

VIENNA CONVENTION ON PROTECTION OF OZONE LAYER

The convention was presented in 1985 and entered into force in1988. This is one of the most ratified conventions by almost 197 countries.

General obligations

1) Co-operate by means of systematic observation, research and information exchange in order to better understand and access the effects of human activities on the ozone layer and the effects on human and environmental health from modification of ozone layer.
2) Adopt appropriate legislative and administrative measures to reduce or prevent the adverse effects of human activities resulting in the modification of ozone layer.
3) Cooperate with competent international bodies to implement this convention.

Research and systematic observation

The parties shall undertake research and scientific assessment on:

i. Physical and chemical processes may affect the ozone layer.
ii. Human health and other biological effects deriving from any modification from ozone layer particularly those resulting from changes in *ultraviolet-b* solar radiations having biological effects.
iii. Climatic effects deriving from modification of ozone layer.
iv. effects deriving from any modification of ozone layer and any change in *ultraviolet b* radiations on natural and synthetic materials useful to mankind.
v. Substances, practices, processes and activities that may affect the ozone layer and their cumulative effects.
vi. Alternative substances, renewable and green technologies must be adopted.

MONTREAL PROTOCOL ON OZONE DEPLETING SUBSTANCES

The Montreal Protocol was about the substances that deplete the ozone layer of the stratosphere. It is an international treaty, designed to protect the ozone layer, by phasing out the production of numerous substances believed to be responsible for ozone depletion. The Treaty was opened for signature on 16th September 1987 and entered into force on 1st January 1989. Its first meeting was held at Helsinki in May 1989. Since then, it has undergone seven revisions and amendments as following:

London (1990) (UK)

Nairobi (1991) Kenia

Copenhagen (1992) Denmark

Bangkok (1993) Thailand

Vienna (1995) Austria

Montreal (1997) Canada

Beijing (1999) Chaina

Kigali amendment (2016) Rwanda

It was believed that if this international agreement is adhered to, the ozone layer would recover by 2005. Initially, the target was set to remove harmful chemicals like the CFCs by 50 per cent by 1998. The target was further revised to curtail the production of these chemicals at the earliest. It has been ratified by the highest198 recorded states among all protocols.

Annexures'

Annexure-A
group#1 five chemicals of CFCs
group#2 three chemicals of Halons (fluorine, chlorine)
Annexure-B
group#1: ten chemicals: products of CFC`s
group#2: carbon tetrachloride (CCl_4)
group#3: Methyl chloroform CH_3CCl_3)
Annexure-C
group#1: four chemicals of Hydrofluorocarbons (HCFC`s)
group#2: thirty-four (34) chemicals of hydro bromo fluorocarbon's
Annexure-D
List of products containing controlled substances specified in annexure-A.
Annexure-E
Methyl bromide (CH_3Br) (only one chemical)
Annexure-F
Group#1: seventeen chemicals of HCFC`s
group#2: only one chemicals CHF_3

phaseout schedule of ozone depleting substances

Chemicals	**Industrialized countries**	**Developing countries**
CFC`s	100% (1999)	20% (2003) 50% (2005) 80% (2007) 100% (2010)
Halons (Cl, Fl etc.)	100 % (1994)	50% (2005) 100% (2010)
Ccl_4	100 % (1996)	85% (2005) 100% (2010)
Methyl chloroform CH_3CCH_3	100 % (2010)	30% (2005) 70% (2010) 100% (2015)
HCFC`s	35% (2004) 65% (2010) 90% (2015) 100% (2020)	100% (2030)
HFC`s	45% (2024) 85% (2036)	80% (2045-2047)

HBFC	100% (1996)	100 % (1996)
Methyl bromide	25% (1999) 50% (2001) 70% (2003) 100% (2005)	20% (2005) 100% (2015)
Bromo-chloro-methane	100% (2002)	100% (2002)

AMENDMENTS IN THE MONTREAL PROTOCOL

4) **London amendment**
In London amendment restriction on halons and CFCs were made more stringent and two new substances i.e tetra chloromethane and methyl chloroform were added in the list of controlled substances.

5) **Copenhagen amendment**
In this amendment, restrictions on the tetra chloromethane, methyl chloroform, halons and CFCs were made more stringent and HFCs and HBFCs and methyl bromide were added in the list of controlled substances.

6) **Montreal**
In this amendment, the parties decide to phase out the schedule of methyl bromide from 20005 to 2010. It also requires the parties to establish the license system for the import and export of ozone depleting substances to control the illegal trafficking of controlled substances.

7) **Beijing amendment**
In this amendment, a new chemical, bromochloromethane was added in the list of controlled substances and a complete ban was imposed on the import and export of the ODS to the countries who have not yet ratified the convention on the Copenhagen amendment.

8) **Kigali amendment**
Adopted on October 15, 2016, in Kigali, Rwanda. It's legally binding, most recent amendment to the Montreal protocol. This aims to reduce the consumption and production of hydrofluorocarbons (HFCs).
The amendment sets out an HFC phasedown schedule, aiming to reduce consumption by 45% by 2024 and 85% by 2036, compared to 2011-2013 levels for group-1(developed countries). Group-2 (under developing e.g. China, India, Brazil) will reduce consumption by 80% by 2045. There are exceptions for some countries like India and middle East countries, which have a more extended date until 2047.

CALCULATING ODS SPECIE AND IT`S NUMBERS

ODS formulas and their specific numbers are crucial for understanding the impact of these substances on the environment. We can find out the specific specie of CFCs, HFCs and Halons from their numbers using it`s formula and vice versa. Suppose a CFC like $CFCl_3$. So, to find its specific number, following three formulas are under consideration.

i. Number of carbon atoms – 1= …….

ii. Number of hydrogen atoms -1=……

iii. Number of fluorine atoms =……..

Examples of finding number from formula

$CFCl_3$	**$C_2F_4Cl_2$**	**$C_2H_2FCl_3$**
=0 0+1=1 1 = 1 11 is the number of this CFC, so called CFC-11.	2-1=1 0+1=1 4=4 114 is number this CFC, so called CFC-114.	2-1=1 2+1=3 1=1 113 is the number of this CFC, so called CFC-113

FINDING FORMULA FROM NUMBER

According to the above formula, in any given number the first number from left indicate carbon, the 2nd is hydrogen and last indicate fluorine. Suppose a given number is 204 in which two indicate carbon, zero indicate hydrogen and four indicate fluorine number. The remaining carbon valencies will satisfy by chlorine.

If a number is given to find formula, you will add ninety (90) in this number and then to find out the formula.

Examples

114	**131**	**160**
114+90= 204 Carbon = 2 Hydrogen = 0 Fluorine= 4 So, CFC is **$C_2F_4Cl_2$**	131+90= 221 Carbon= 2 Hydrogen = 2 Fluorine= 1 The remaining three bond can be made by chlorine with carbon. The CFC is **$C_2H_2FCl_3$**	**160+ 90= 250** **Carbon= 2** Hydrogen = 5 Fluorine= 0 **C_2H_5Cl**

Finding formula from number of halons family

As these are almost volatile hydrocarbons, carbon is the backbone. In this way in formula, the placing order is carbon, fluorine, chlorine and bromine respectively. This must be under consideration that any halon can be absent except bromine. Examples are as following.

2	2	3	1
carbon	fluorine	chlorine	bromine

by this sequence the chemical is **C_2FCl_3Br**

If one halon is not present

Example:2

2	5	0	1
carbon	fluorine	chlorine	bromine

OZONE DEPLETING POTENTIAL (ODP)

ODP is a dimensionless number that compares the potential of a substance to deplete the ozone layer relative to a reference substance, typically trichlorofluoromethane ($CFCl_3$) called CFC-11, which has an ODP of 1.0. This reference molecule is considered to destroy ten thousand (10000) molecules of ozone layer. ODP is calculated based on the amount of ozone depletion caused by a substance, considering factors like it`s atmospheric lifetime, chlorine and bromine content and reactivity. ODP has complected calculations which scientists used for special purposes, but a simple calculation is as follows.

ODP = number of ozone molecules destroyed/10000

Example

ODP = 100000/10000

ODP = 10

If the ODP of a substance is given, we can calculate the ozone molecules destroyed by that substance as following,

example: CFC-113

0.6 = no of O_3 molecules destroyed/10,000\

number of O_3 molecules destroyed = 0.6 ×10,000

number of O_3 molecules destroyed = 6000

To find consumption, production and kilogram per capita

The following formulas and calculations are only for annexure-A substances of the protocol. The consumption of ODS greater than 0.3 kg per person are considered as industrialized countries while consumption less than this vale is considered as developing countries.

Consumption = P(production)× ODP + I(import) ×ODP – E(export)×ODP – AD (amount destroyed) ×ODP

Example

Group-1	ODP	P(kg)	I(kg)	E(kg)	AD
CFC-11	1	20	2	10	0
CFC-12	1	5	4	0	0
CFC-113	0.6	50	6	10	1
CFC-114	1	10	0	0	0
CFC-115	8	5	1	0	0
Group-2 Halons-A	3	30	2	10	2
H-B	10	40	0	10	2
H-C	6	10	0	2	0

First, we must calculate the consumption from above formula. Then divide the consumption value on population to get kg per capita a following.

Kg/capita = consumption ÷ population

Question: a specific ozone depleting specie namely CFC-113 has ODP value 0.6. suppose if a country`s production is 500 kg, import is 60 kg, export is 100 kg and amount destroyed is 20 kg per Anum. Calculate the total consumption of the country and per capita use, if country have total population 20000000.

Solve: Consumption = P(production)× ODP + I(import) ×ODP – E(export)×ODP – AD (amount destroyed) ×ODP

Consumption= 500×0.6 + 60×0.6 – (100× 0.6)- (20×0.6)

= 300+36 -60-12

=336-72

=264 kg

Kg/capita/Anum = consumption ÷ population

=264 ×1000

=264,000 grams ÷20,000,000

=1.32 grams

VIANNA AND MONTREAL IMPLEMENTATION IN PAKISTAN

- Pakistan ratified these two agreements on 18 december1992.
- The ministry of environment establishes the ozone cell in 1996.
- Global environmental fund denoting company funded Pakistan for projects.
- United nation industrial developing organization (UNIDO) launched more than fifty (50) projects in Pakistan to phaseout CFCs from industries.
- By the implementation of these agreements, Pakistan become successful for its CFC and halons phaseout (CFC and halons phaseout schedule for Pakistan was 2010 and 2015 respectively). Pakistan is currently using HFCs.
- First-generation ODS are largely phase outed. the second- generation ODS(HCFCs) now progress in Pakistan with a 67.5% reduction target until 2025 for 3rd reduction step under article-5 of the Montreal.
- Pakistan will reduce 97.5% until 2030 for it`s 4th reduction step. And only 2.5% allowed for service until 2040.

CHAPTER 12 ENVIRONMENTAL IMPACT ASSESSMENT AND ENVIRONMENTAL LAWS

In the Pakistan environmental protection act 1997, subsection (2), clause 11, the EIA is defined as "Environmental study comprising of data collection, prediction of qualitative and quantitative impacts, comparison of alternatives, evolution of preventive, mitigatory and compensatory measures, formulation of environmental management and training planning and monitoring arrangements and framing of recommendations and such other components as may be prescribed."

Difference of EIA and IEE

Initial environmental examination (IEE) is Initial screening of environmental issues and concerns for a proposed project, for the purpose of whether the EIA is required or not. The Pakistan environmental protection act, in its subsection (2), clause fourteen define the IEE as "A preliminary environmental review of the reasonably foreseeable qualitative and Quantitative impacts on the environment of a proposed project to determine whether it is likely to cause an adverse environmental effect for requiring preparation of an Environmental impact assessment."

This is Typically required for smaller-scale projects or those with limited potential impacts. The EIA study requires a detailed report while IEE can be covered by a brief report or statement. This also does not involve public consultation or stakeholder engagement.

Environmental protection agency

According to the Pakistan environmental protection act/Balochistan environmental protection act 2012; subsection (5), clause 1, The federal/provincial government in its official gazette, establish the Pakistan/Balochistan environmental protection agency. Under the provisions of the acts, the agencies have powers and can perform functions, can make rules and regulations.

Competent authority

The authority under act has powers and responsibilities and performs functions regarding guidelines, rules and regulations and their implementation. This authority in environmental context is an environmental protection agency.

Proponent: under act means the person or organization who proposes or intends to undertake a project.

Consultant: a third person or organization appointed by a project proponent to prepare an IEE/EIA under the registration or NOC (no objection certificate) by the relevant EPA.

Environmental tribunal: the tribunals were established under the Pakistan environmental protection act 1997, section (20). These are headed by a chairman and two members, one technical (environmental expert) and the other one is legal (Judge).

The tribunal provides a legal framework to assist in protecting the environment.

Environmental magistrate: the environmental magistrates established under section (24) of environmental protection act 1997, consist of senior civil judges to take all contraventions punishable in respect of handling of hazardous substances and pollution of motor vehicles.

Environmental protection council means council established under section (3), subsection (1) of the Pakistan environmental protection act consists of a chairperson, vice chairman

and environmental experts and experts of the attached departments not exceeding than thirty-five (35).

An environmental protection order is issued when the federal/provincial agency determines whether the discharge or emission of any effluent, waste, air or noise pollution, disposal of waste, or the handling of hazardous substances, or any other act or omission is likely to occur or is occurring.

Annual environmental report: the annual environmental report is designed by environmental protection authorities to facilitate licenses to provide the public with a concise summary of your environmental performance and of on-going developments on your site over the previous year.

EIA PROCESS

The Environmental Impact Assessment (EIA) process is a systematic evaluation of the potential environmental impacts of a proposed project, policy, or program. In Pakistan, the EIA process is governed by many acts, laws, guidelines (some sectoral ones) and regulations. The most common are Pakistan Environmental Protection Act and guidelines 1997, Pakistan EIA Regulations, 2000, the Balochistan environmental protection agency (review of IEE and EIA) regulations 2020 and statutory (S.R.O) notification by the ministry of climate change.

The EIA procedure generally requires screening, scoping, preparation of Terms of Reference for the EIA, assessment and preparation of an EIA report, public notification and public hearing, and review. Thereafter, a decision on the EIA approval is taken and follow-up compliance monitoring is required. Important documents of the process are the Scoping report, TOR and EIA report.

The process involves:

1. SCREENING: PROCESS

Screening is a required step and conducted by the EPA at federal level and by Provincial EPAs at provincial level. In Pakistan, two levels of environmental assessment are distinguished: Initial Environmental Examination (IEE) and full EIA. Screening is based on both preliminary IEE and positive lists (schedules) contained in the EIA Regulations, 2000 or in the relevant schedules in provincial regulation as Balochistan EPA (Review of IEE and EIA) regulations,2020. These schedules prescribe the groups of activities that require either an IEE or an EIA.

Schedule I lists activities subject to IEE with maximum thresholds. Activities that exceed these thresholds are all listed in Schedule II and are subject to EIA.

Schedule II also lists other activities, without minimum thresholds, that require EIA. EPA at Federal or provincial level may, if it deems appropriate, directly request a proponent of certain project to submit an IEE or EIA even if not listed in schedule II or I.

The preparation of the IEE and the screening stage of an EIA are not open for other stakeholders apart from the proponent and the EPA.

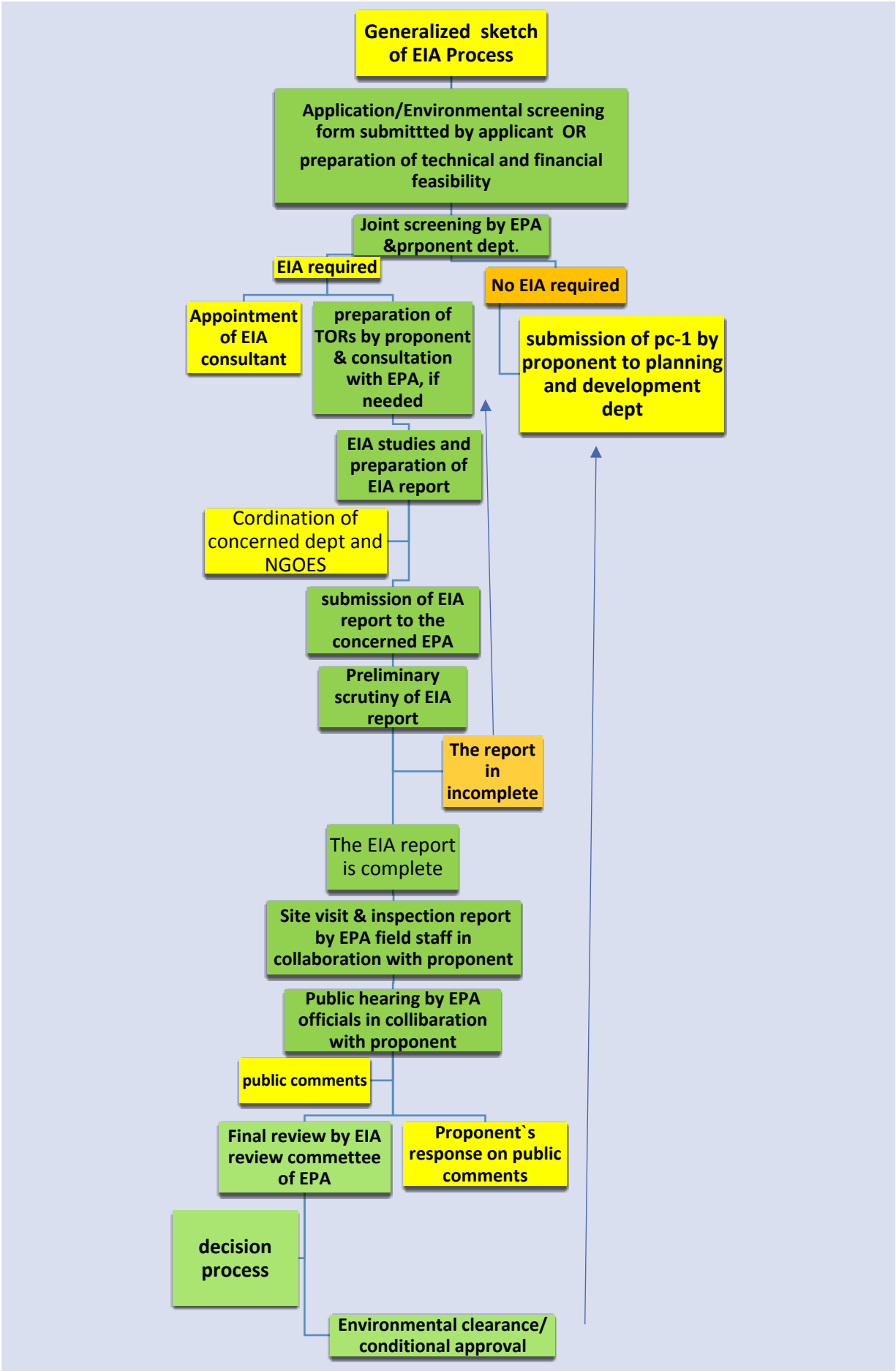
Additionally, sectoral guidelines contain checklists of environmental parameters that can be used to aid screening decisions.
All activities within environmentally sensitive areas require a full EIA. The guidelines advise on the procedure to be followed for projects which (might be) located in these areas. In these cases, the proponent is required to contact the Conservation Authority for advice.

2. SCOPING AND TORS

The proponent formulates the Terms of Reference; these do not have to be approved. The basis for determining the scope of the EIA derives from the sectoral guidelines, which includes a checklist on likely impacts and mitigation measures for several activities.
According to the guidelines, scoping process with a document consists of description and objectives of the project, context and setting of the proposal, constraints, alternatives, issues, public involvement and timetable.
The proponent of the project and his consultant will develop the outline of scoping through discussion with relevant EPA and other key stakeholders such as attached departments and NGOs.
• Make outline and supporting information available to those whose views are to be obtained.

CONTENTS OF THE SCOPING DOCUMENT

The scoping document should contain objectives and description of the activity, the context and setting of the activity, constraints, alternatives, public involvement, timetable.


Generalized sketch of EIA Process
Application/Environmental screening form submittted by applicant OR
preparation of technical and financial feasibility
Joint screening by EPA &prponent dept.
EIA required
No EIA required
Appointment of EIA consultant
preparation of TORs by proponent & consultation with EPA, if needed
submission of pc-1 by proponent to planning and development dept
EIA studies and preparation of EIA report
Cordination of concerned dept and NGOES
submission of EIA report to the concerned EPA
Preliminary scrutiny of EIA report
The report in incomplete
The EIA report is complete
Site visit & inspection report by EPA field staff in collaboration with proponent
Public hearing by EPA officials in collibaration with proponent
public comments
Final review by EIA review commettee of EPA
Proponent`s response on public comments
decision process
Environmental clearance/ conditional approval

ASSESSMENT AND EIA REPORTING

regular methods for assessment are not specified in the EIA regulations of 2000 on federal level. The relevant Agencies issued guidelines for preparation of an IEE or an EIA, including guidelines of general applicability, and sectoral guidelines indicating specific assessment requirements for planning, construction and operation of projects relating to particular sector.

The guidelines for preparation and review of environmental reports of Pakistan November1997, give a general procedure that include impact identification, baseline data collection, prediction, social, health as well as economic and fiscal impacts and significance of impacts and consider the alternatives to reduce the impacts. For each impact, these aspects should be considered: nature; magnitude; timing; duration; reversibility and likelihood (risk).

Under the impact identification, some advantageous methods including checklists, matrices, networks, overlays and GIS expert system etc., are required. The Guidelines for the Preparation and Review of Environmental Report indicate that environmental, social, health and economic impacts shall be considered in the EIA report.

CONTENTS OF THE EIA REPORT

It is advised that an Environmental Report should contain:

• Executive or non-technical summary.

• Description of the objectives of the proposal.

• description of the proposal and its alternatives.

• discussion of the proposal and current land use and policies.

• description of existing and expected conditions.

• evaluation of the impacts for each alternative.

• comparative evaluation of alternatives and identification of the preferred option.

• environmental management plan, monitoring plan and proposed training.

• appendices.

REVIEW FEES

at the time of submission of an IEE or EIA report, the proponent of the project must pay a non-refundable review fee to the relevant agency (as specified in Schedule iii of Pakistan environmental protection agency (review of IEE and EIA) regulations, 2000).

FILLING OF IEE/EIA WITH EPA

Total twelve copies (ten paper copies and two electronic copies) of an IEE/EIA shall be filled with agency. Every IEE and EIA shall be accompanied by:

(a) an application, in the form prescribed in Schedule IV; and

(b) copy of receipt showing payment of the Review Fee.

PRELIMINARY SCRUTINY

After the Identification of sensitive areas or assets that could be impacted by the project, Assessing potential security risks, such as, Unauthorized access, Sabotage, Terrorism, Cyber-attacks, the environmental protection agency (as in the above flow chart) Within 10 working days of filing and submission of the IEE or EIA reports, the Agency shall,

(a) confirm that the IEE or EIA is complete for purposes of initiation of the review process; or (b) require the proponent to submit such additional information as may be specified; or

(c) return the IEE or EIA to the proponent for revision, clearly listing the points requiring further study and discussion.

Other additional information and data required by EPA during the review process must be provided by the proponent.

PUBLIC PARTICIPATION/PUBLIC HEARING

As in preliminary scrutiny, when EPA confirm that (in case of EIA) report is complete for review process, then it be published in any English or Urdu national newspaper and in a local newspaper of general circulation in the area affected by the project, a public notice mentioning the type of project, its exact location, the name and address of the proponent and the places at which the EIA of the project is taken.

The notice issued in the newspaper for public participation shall fix a date, time and place for the public for comments on the project or its EIA. This notice shall fix the date of public hearing not earlier than a month (30 days).

The agency may issue guidelines for public participation, indicating the basic techniques and measures to be adopted to ensure effective public consultation, involvement and participation in EIA assessment.

this shall be ensured by the Agency that the circulation of the EIA to the concerned Government Agencies, attached departments and NGO and grant their comments on this. All comments received by the Agency from the public or any Government Agency shall be collected, tabulated and duly considered in review process before decision on the EIA.

REVIEW PROCESS

IEE and EIA will be reviewed by government experts of concerned and attached government departments, NGOs and affected community members are also permitted to

review the reports by the consultation of EPA. The Environmental Protection Agency shall make every effort to carry out its review of the IEE within 45 days, and of the EIA within 90 days (3 months), after replying in preliminary scrutiny of the issue of EIA report completeness. The collective time of four months (1 month of public participation and three months of review) of review may be extended in particular case for approval.

In reviewing the IEE or EIA, the Agency shall consult a Committee of Experts as may be constituted for the purpose by the Director-General and may also take the views of the Sectoral Advisory Committee and any other constituted by the Government. The Director-General himself is authorized, where he considers necessary, to constitute a committee to inspect the site of the project and submit its report on such matters as deem necessary.

The review of the IEE or EIA by the Agency shall be based on quantitative and qualitative assessment of the documents and data furnished by the proponent, comments from the public and Government Agencies. The stepwise detail review process is described in the EIA guidelines for preparation and review of environmental reports.

DECISION MAKING

The proponent of any activity listed under schedule I and II of the EPA-IEE and EIA regulations, 2000 needs formal IEE or EIA approval from the EPA (called environmental approval) before any project approval.

On completion of the review process, the decision of the Agency shall be communicated to the proponent in the form prescribed in Schedule V in the case of an IEE, and in the form prescribed in Schedule VI in the case of an EIA. Decisions are justified in writing. Schedule IV of the EIA regulation, 2000 provides a form that EPA uses as a decision note. The EIA guidelines stipulate that a register of decision is made available to the public. It does not however state whether the decision should be published.

. The decision-making procedure depends on whether private sector or public sector projects are being considered. The final decision on Environmental Approval for private projects is taken by the responsible authority (EPA, provincial or district authorities in co-operation with other Departments and Agencies). In case a public project, decision is taken on environmental approval of EPA in the form of PC-1 by Planning and development department and all attached departments.

CONDITIONAL APPROVAL

The approval given by the agency is in the terms that the project shall be designed and constructed, and mitigatory and other measures adopted, strictly in accordance with the IEE/EIA process. Any changes in the document which are deemed necessary by EPA shall be given in approval.

Before the start of the project construction-phase, an undertaking (as in the schedule vii of the Pak-EPA, IEE/EIA regulations, 2000) in the reply of approval letter is given by proponent to EPA, specifying that he will design, construct and operate strictly in accordance with the said conditions i.e of the IEE/EIA report.

Before commencing operation of the project, obtain from the Federal Agency written confirmation that the conditions of approval, and the requirements in the IEE/EIA relating to design and construction, adoption of mitigatory and other measures and other relevant matters, have been duly complied with.

VALIDITY OF APPROVAL

The approval is valid for a period of three years, further extension of three years can be given in terms, if construction started in the initial three years. on the request of proponent in initial three years periods, the validity may extend but cannot be more than three years at a time. The validity can also be extended to three years from the date of confirmation of the compliance.

CONFIRMATION OF COMPLIANCE

The EPA may want some additional information for the IEE/EIA report on approval process. Compliance with the provisions can be in the form of an environmental management plan. The EPA may visit the project site and can inspect machinery etc. and may also require information, which is deemed necessary, from the proponent within fifteen (15) days.

PENALTIES OF NON-COMPLIANCE AND CANCELLATION OF APPROVAL

If any information or data of IEE/EIA report is incorrect or may not comply with provisions of EPA. and at any time, based on information or report received or inspection carried out, the approval conditions are violated. EPA has authority to issue notice/ show cause within two weeks of the information received, to inform the proponent of violation. If any reply is not received from the proponent or received an unsatisfactory response, the EPA may give an opportunity of being heard, require the proponent to take such measures and to comply with such conditions within such period as it may specify and failing to comply shall stand the approval cancelled or even cancel. On the cancelation of approval, the proponent must cease the activity immediately.

ENVIRONMENTAL MANAGEMENT PLAN (EMP)

An EMP is a document designed to ensure that the comments in the environmental report after review process and approval of EIA are fully implemented. It is a detailed and comprehensive document usually prepared during or following detail designed of the proposal, after environmental approval of the development application.

A detailed EMP is usually not part of the Environmental Report, but rather a comprehensive outline of the structure of it with a summary of the management principles to be followed. For issues of high risk and uncertainty, details of management should be included in this outline.

The EMP should provide a framework for managing and mitigating environmental impacts for the life of the project.

MONITORING

In the post construction phase, the proponent shall submit a report to the Federal

Agency on completion of construction of the project. After confirmation of compliance during construction, the proponent shall submit an annual report summarizing operational performance of the project, with reference to the conditions of approval and maintenance and mitigatory measures adopted by the project.

Form of registers of IEE and EIA projects

The EPA maintains form of registers for the registrations of projects and their proponents and consultants' data. Approval date and undertaking with its relevant provisions. Full data is available in schedule eight (8) of national (review of EIA/IEE) regulations,2000.

Environmental assessment advisory committee

This committee was launched under the national (review of EIA/IEE) regulations,2000, for the purposes of rendering advice on all aspects of environmental assessment, including guidelines, procedures and categorization of projects, the Director-General shall constitute an Environmental Assessment Advisory Committee consisting of four members including the director general as a chairman.

CHAPTER 13 WATER QUALITY, ANALYSIS AND TREATMENT

WATER QUALITY

Drinking water quality refers to the overall condition of water in terms of its physical, chemical, and biological characteristics that determine its safety for human consumption. Safe drinking water should be clear, free from harmful chemicals and microorganisms, and have an acceptable taste and odor. Parameters such as pH, turbidity, hardness, total dissolved solids, and bacterial content are used to assess quality. Organizations like the WHO and national agencies set standards to ensure water safety. Maintaining good drinking water quality is vital for public health, as contaminated water can cause serious diseases and long-term health problems.

ANALYSIS OF THE PHYSICAL PARAMETERS OF POTABLE WATER

The physical parameters of drinking water refer to its observable qualities such as color, taste, odor, temperature, and turbidity. These factors affect the water's appearance and acceptability for consumption. Clear, colorless, and odorless water is generally considered safe and pleasant to drink, while high turbidity or unusual color and odor may indicate contamination from suspended particles or organic matter. Monitoring physical parameters helps ensure that water is both safe and aesthetically suitable for human use.

SUSPENDED SOLIDS (SS)

A well shacked sample of water filtered through a pre weighed standard glass fiber filter and the residue retained on the filter is dried at 103 to 105°C. The increase in weight of the filter represents the total suspended solids.

Total suspended solids (TSS) = (W1-W2)*1000/ml of sample

W1= Initial weight of filter in mg

W2. Final weight of filter in mg

Totol dissolve solids(TDS)

The total dissolved solids (TDS) of the samples were measured using pre-calibrated TDS meter model InoLab TDSLevel-1. Before measurement, the beaker and electrode must be washed several times with the solution under test or through distilled water. The measurement was taken at room temperature. The samples were poured into beaker in specific volume to dip the electrode, after which the button was pressed and the scale was set before the TDS of each sample was noted.

ELECTRICAL CONDUCTUCTIVITY

It is the ability of an aqueous solution to carry the current. Increase in ionic concentration improves the electric conductivity. Electric conductance measures the ionic process of a solution that allows it to transmit current.electric conductance is expressed in terms of micro siemens per centimeter(uS/cm) or millisiemens per centimeter(Orena & Gurmessa,2008).

Procedure:

The conductivity of water samples was determined in laboratory through "water quality checker" and with conductivity meter. First of all the instruments were washed with distilled water for correct measurement,then samples were taken in 100 ml beakers in such amount to immersed the electrode/bulb of meter in it.

Using water quality checker, the conductivity mode was selected and reading was recorded. Electrode was washed with distilled water before putting in water sample. The same procedure was repeated for all water samples.

Calibration

For calibration of conductometer 0.01 M solution of KCl will give 1412µmo/cm orµS/cm.

TEMPERATURE

It is define as "average kinetic energy of body". It is an important factor because its having effects on chemical and biological reactions in water. An increase of 10^{o}C is usually sufficient to double the biological activity.

Procedure:

can be measured simply by using "The water quality checker". The bulb/electrode was immersed in an inclined position just beneath the surface of the water and the temperature was noted. The most significant measurement of temperature is on source.

Some Physical Parameters of Water Samples of district Zhob as an example

No	Location	Source	Suspended Solids	TDS (mg/L)	Electric Conductance (µS/cm)	Temperature (C^{o})
1	Badin Zai	Kareez	20	382	570	13.1
2	Kochai Zai	Kareez	6	272	410	12.9
3	Wani	Kareez	43	294	470	13.1
4	Khut Kanda	Kareez	101	485	650	12.8
5	Khado Zai	Tank	72	442	620	12.9
6	Rukhpoor	Bore	10	392	580	13.3
7	Zhob city	Bore	120	1008	1400	12.9
WHO				500	1500(No limit, But effect other parameter)	25
PCRWR				500	1500	25

Equivalent weight in chemistry of solutions

The equivalence of an element or radical is defined as "the number of hydrogen atoms that an element or radical can hold in combination or can replace in a reaction.

An equivalent of an element or a radical is its grams molecular mass divided by its equivalence. A mill equivalent is the equivalent weight expressed in small amounts because concentrations of dissolved substances are more often in the milligrams per liter range.

How many grams of calcium will be required to combine 120g of carbonate (CO_3^{-2}) to form calcium carbonate?

One equivalent (equivalent weight) of CO_3 = molecular mass ÷ valance

= 12 + 3(16) ÷ 2 = 60 ÷2

=30 grams/equivalent

One equivalent (equivalent weight) of Ca =40÷ 2

Calcium =20 grams/equivalent

=concentration of CO_3/one equivalent of CO_3

= 120g/30 g/equi

=6 equivalent

Calcium= 6 equivalent × 20 grams/equivalent

Calcium=120 grams

Example#2what is the equivalent calcium carbonate ($CaCO_3$) concentration if concentration of NaCl is170mg/L.

One equivalent (equivalent weight) of calcium carbonate $CaCO_3$ =

= molecular mass ÷ valance

=40+ 12 + 3(16) ÷ 2

=50 grams/equivalent

= 50,000 mg/equiv=50mg/mequiv

One equivalent (equivalent weight) of sodium chloride (NaCl)=23+35.5 ÷1

=58.5grams/equivalent

= 58.5 mg/mequiv

=concentration of NaCl/one equivalent of Nacl

= 170mg/L ÷58.5mg/mequiv

=2.9 mili equiv

=2.9 mequiv ×50 mg/mequiv

=145 mg/L of $CaCO_3$

CHEMICAL PARAMETERS OF POTABLE WATER

The chemical parameters of drinking water include the concentration of various dissolved substances and compounds that affect its safety and quality. Important indicators are pH, hardness, total dissolved solids (TDS), and the presence of chemicals such as fluoride and chloride. These substances can come from natural sources or pollution caused by industrial, agricultural, and domestic activities. Maintaining chemical parameters within standard limits is essential to prevent toxic effects and ensure the water remains safe for human consumption. Following are some chemical parameters of drinking water and its analysis.

PH

It is define as “power of hydrogenion concentration in water”. pH indicates the strength of an acidic or basic solution. The pH scale ranging from 0 to 14. The middle of the range i.e pH 7 represent a neutral solution. Pure water is neutral because it contains the same number of hydrogen ions as hydroxide ions. Solutios with pH values less then 7 are acidic and those with pH values greater than 7 are alkaline or basic.

Procedure:

pH was determined through pH meter. We took water of all seven samples in 100 ml beakers . pH meter have two electrodes, one of which is for water. We immersed the electrode in each sample then observed and noted the pH value. It gives maximum and manimum values. By adding and dividing on two, we determined the average pH *p*Hvalue. We washed the electrode through distilled water when determining the next sample. pH meter was calibrated with pH 4, 7 and 11 buffer solutions.

ALKALINITY

Alkalinity is define as “the capacity to neutralize water”. Alkalinity is the sum of total components in water that tends to evaluate the pH of water above the value 4.5.

Alkalinity is the presence of one or more ions in water including hydroxides, carbonates, and bicarbonates. In alkalinity acid(H_2SO_4 normality 0.02) titration curve all hydroxyl ions(OH^-) and half of carbonates will nutralize at P_H 8.3 , this will be called P-alkilinity. Other half of carbonates and bicarbonates will nutralize at p_h 4.3. this is the Methyl orange or total alkalinity. So basic two types of alkilinity have following five forms;

If P=M allalkalinity is OH^-

P= M/2 all alkalinity is OH^-

P= M/2 all alkalinity is CO_3^{-2}

P=0 (E=i.e initial p_h is below 8.3) all alkalinity is HCO_3

P< M/2 predominant species are CO_3^{-2} and HCO_3^{-1}

P>M/2 predominant species are OH^- ans CO_3^{-2}

impacts

Moderate concentration of alkalinity is desirable in most drinking water supplies to stable the corrosive effects of acidity. However, excessive quantities may cause a number of damages, such as bitter taste to drinking water and precipitate can foul and block pipelines.

Alkilinity is expressed as miligrams per liter of $CaCO_3$. This is because most alkalinity in water is due to calcium and its carbonates.

Reagents

1Normality sulfuric acid solution

Take 27 ml of concentrated sulphuric acid and dilute it up to 1 litre distilled water in volumetric flask this is stock solution.Now take 20 ml from this 1N solution and dilute this 1 liter in volumetric flask to 0.02 N.

Calculation

One mole of H_2SO_4=98 g

Equivalent w.t(H_2SO_4)=49 g

Density of H_2SO_4=1.84 g/ml

V=mass(g)/density=49g/1.84g/ml

V=26.63 ml Average purity of H_2SO_4=96.5 %

100×26.63/96.5=27.25 ml

2)Panapthelene indicator

2-3 drops in each sample

3)methyl orange indicator

One(1) drop in each solution

Make 1 N of stock solution then dilute it to 0.02 N working solution as following:

standardization

N2 ×V2=N1 ×V1

V2= N1 V1/N2

$$V2 = \frac{1N \times 20\ ml}{0.02\ N}$$

V2 = 1000 ml

So to prepare 0.02 N dilute H_2SO_4 solution , 1000 ml volume

will be required for 1N of 20 ml.

Procedure(Acid-base titration method)

In first we took 100ml burret with stand and filled the burret with dilluted sulphuric acid solution of normality 0.02. Then took 20 ml sample in beaker and added 3 drops of panapthelene.most of which show purple colour instead of pink, which indicates that p-alkalinity is very less.

we proceed the procedure and added 1 drop of methyl orange in the same sample,which gave yellow colour indicates M-alkalinity .

Then we titrate the acid in the same sample by noting the initial and final readings till yellow color changed to more orange, this is the complete Methyl orange alkalinity which indicates total alkalinity.

This procedure was repeated for all seven samples.

Calculation

$$\text{Alkalinity as } CaCO_3 = \frac{\text{use of sulphuric acid} \times N \text{ of acid} \times \text{equivalent w.t of } CaCO_3 \times 1000}{\text{ml of sample used}}$$

Q#1 A 200 ml sample of water has an initial pH of 10. 30 ml of 0.02 N sulphuric acid (H_2SO_4) is required to titrate the sample to pH 4.5. what is the total alkalinity of the water as $CaCO_3$.?

Solution:

$$\text{Alkalinity as } CaCO_3 = \frac{\text{use of sulphuric acid} \times N \text{ of acid} \times \text{equivalent w.t of } CaCO_3 \times 1000}{\text{ml of sample used}}$$

$$= \frac{30ml \times 0.02\ N \times 50 \times 1000}{200ml}$$

Total alkalinity = 150 mg/l as $CaCO_3$.

Q#2 determine the species and quantity of each specie of alkalinity in abve equation if the 8.3 equivalence point is reached at 11ml of acid.

Solution:

Addition of 11 ml acid reduce the initial pH 10 to 8.3 , which is P-alkalinity

$$= \frac{11ml \times 0.02\ N \times 50 \times 1000}{200ml}$$

$$= 55 mg/l \text{ as } CaCO_3$$

Total alkalinity = 150/2

$$= 75\ mg/l \text{ as } CaCO_3$$

$55 < 75$

$P < M/2$ SO predominant species are (CO_3^{-2}, HCO_3^{-1})

Initial pH of water is 10 so initial POH^- IS 4

$POH = 10^{-4} = 0.0001$ moles

$$OH^- = \frac{0.0001 \text{ moles } OH^-}{L} \times \frac{50 \text{ mg/l as as } CaCO_3 \times 1000}{1 \text{ equiv}} \quad \frac{1 \text{ equiv}}{\text{mol } OH^-}$$

$[OH^-] = 5\ mg/l$ as $CaCO_3$

Concentration of carbonate = P-alkalinity - $[OH^-]$

$= 55 - 5$

$= 50$

Half of corbonates are in P-alkalinity and other half in M- alkalinity(total alkalinity)

$= 50 + 50$

$[CO_3^{-2}] = 100\ mg/l$ as $CaCO_3$

Bicarbonates = total alkalinity - $[CO_3^{-2}]$ + $[OH^-]$

$= 150 - (100 + 5)$

$[HCO_3^{-1}] = 45\ mg/l$ as $CaCO_3$

HARDNESS

Water hardness is the measure of concentration of multivalent metallic cations in solutions. At super saturated conditions the the cations in water will react with anions to form solid which precipitate out. It is also the measure of capacity of water to precipitate soap. In current documents the total hardness is difine as “the sum of the calcium and magnesium concentration, both expressed as calcium carbonate, in milligrams per liter.when the hardness is equivalent to the total alkalinity then it is known as “carbonare hardness” with any remaining hardness being called non-carbonate hardness.

Theoritically the calcium and magnicium are soluble 17 mg/l and 9mg/l respectively, so the carbonate hardness is 26 mg/l but practically calcium and magnicium are 40 mg/l amd 10 mg/l respectively. So we take a standard of 50 mg/l as of calcium carbonate($CaCO_3$).

The hardness may range from zero to hundreds of milligrams per liter, depending on the source and treatment to which the water has been subjected.

Reagents

1)EDTA(Ethylene diamine tetra acetic acid) titration solution:

(3.7 g of EDTA +1000 ml distilled water)

2) buffer solution:

Ammonium chloride(NH_4Cl)=16.9 g

Ammonium hydroxide(NH_4OH)=143 ml)

^{pH} =10

3)EBT indicator (Erichrome black-T):

Add 2 ml or small amount of solid EBT with help of spoon.

Procedure

In the total hardness test procedure, the 25 ml of water samples were first buffered(using an organic amine and one of its salts) by 1ml of solution to maintain its p^H higher.Now we Added 1ml of EBT as indicator in each one of seven samples.EBT is an organic dye which gives purple colour to the sample, after well shaking of beaker, the organic dye will react with calcium and magnesium ions to give a red-colored complex.

EDTA was added as a titrant untill sample colour was changed. The EDTA reacts with all free calcium and magnesium ions in the sample. At the end of the titration, when free magnesium ions were no longer available, EDTA removes magnesium ions from the indicator changes its color from red to blue or violet blue.

Calculation

Hardness (mg/L as $CaCO_3$)= $\frac{A(ml) \times B\ (ml) \times 100 \times 1000}{ml\ of\ sample}$

WHERE

A = ml of EDTA used

B=Molarity of EDTA(0.01)

Standardization

Take 3.723 g EDTA and dissolve in water and heat it slowly..

After dissolving make up a litre in volume measuring flask.

So EDTA(0.01 M) is ready.

$CaCO_3$ standard solution of (0.025 M) equals to 2.5 g/L.

CALCIUM(CA) HARDNESS

Hardness of water is defined as " content of calcium and magnesium ions. Since an analysis does not distinguish between Ca2+ and Mg2+, and since most hardness is caused by carbonate deposits in the earth.Hardness is usually reported as total parts per million calcium carbonate by weight. A water supply with a hardness of 100 parts per million would contain the equivalent of 100 grams of CaCO3 in 1 million grams of water or 0.1 gram in one liter of water. Ca2+ and Mg2+ form insoluble salts with soaps and make a scum that sticks to clothes or to the bathtub.

Reagents

Murexide(Ammonium purpurate) indicator

EDTA(ethylene diamine tetra acetic acid) titration solution

Buffer solution(^{pH} =12.5)

Formula same as total Hardness

Procedure

We took 25 ml sample in graduated cylinder and pour in the titration flask, some milligrams of indicator Murexide(Ammonium purpurate) and some drops of buffer solution(^{pH} =12.5) were added,on this, the solution become pink as Murexide react with Ca ions. Then we started titration very carefully until the color of solution become purple.

Chemical analysis interpretation

Thre are five special cases in this regard for alkalinity and hardness as following:

I. Calcium alkalinity (Ca)= Ca hardness or totsal alkalinity (which ever is smaller)
II. Magnicium alkalinity = *Mg* hardness if total alkalinity is greater(>) or equal (=)than Total-hardness
III. Magnicium alkalinity = T-alkalinity – calcium(Ca) hardness (if total alkalinity is greater(>)than calcium hardness but less than total hardness).
IV. Sodium alkalinity(Na) alkalinity = T-alkalinity – T-hardness
V. Non-corbonate hardness = T- hardness - T-alkalinity (if magnicium alkalinity present then no calcium N-C-H).

Analysis	Water#1	Water#2	Water#3
Total hardness	300	300	300
Ca hardness	200	200	200
Mg hardness	100	100	100
Total alkalinity	150	250	350

Interpretation	Water#1	Water#2	Water#3
Ca alkalinity	150	200	200
Mg alkalinity	None	50	100
Sodium(Na) alkalinity	None	None	50
Ca N-C hardness	50	None	None
Mg N-C hardness	100	50	None

<u>Question no 1 Calculate the hydrated lime(CaO). if</u>

Total hardness = 280 *mg/ l* as $CaCO_3$

Magnicium hardness= 21*mg/ l* as $CaCO_3$

Total alkalinity = 170 *mg/ l* as $CaCO_3$

CO_2 = 6 *mg/ l*

Solution:

I. Carbon dioxide(CO_2) react with calcium Oxide (CaO) so

For CO_2= Concentration of CO_2 × (CaO) equivalent

Equiv ((CO_2) mg/mili equiv

CaO for CO_2 softening (removal) = 6 mg/l × 28 ~~mg/mili equiv~~

22 ~~mg/ mili equiv~~

CaO = 7.6 *mg/l*

3) CaO for alkalinity softening (removal) = 170 mg/l × 28 ~~mg/mili equiv~~

50~~mg/ mili equiv~~

CaO = 95.2 *mg/l*

4) CaO for Mg hardness softening (removal) = 21 mg/l × 28 ~~mg/mili equiv~~

12.15~~mg/ mili equiv~~

CaO = 48.39 *mg/l*

Total calcium Oxide (CaO) required to remove temporary hardnedd

=7.6 + 95.2 + 48.39

= 151.19 *mg/ l* as $CaCO_3$

II. Permanent hardness or non carbonate hardness

N-C-H = total hardness- total alkalinity

=280 -170

= 110 *mg/l*

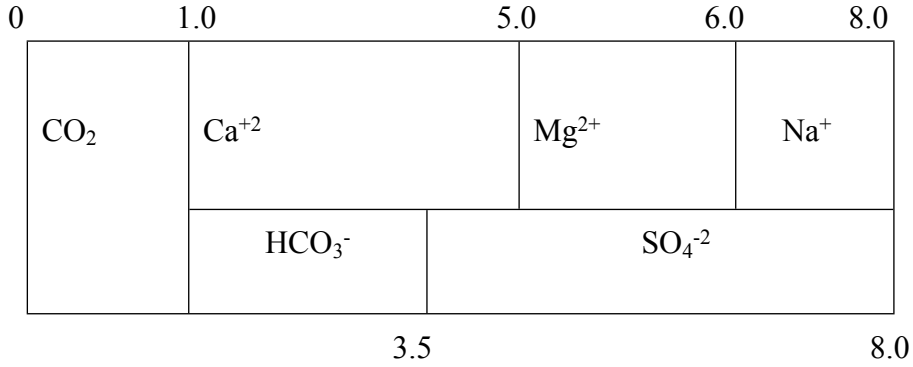
Na_2CO_3(soda ash) = 110/50 ×53

Na_2CO_3 = 116.6 *mg/l*

Q#2: A water with ionic characteristics shown in the bar diagram below is to softened to the minimum calcium hardness by the lime-soda ash process. Magnesium is not deemed necessary.

1) Calculate the chemical requirements and solids produced in miliequivalents per liter.
2) Draw a bar diagram for the finished water.
3) For a flow of 25000 m^3/d , calculate the daily chemicals requirement and the mass of solids produced. Assume that the lime is 90 percent and soda ash is 85 percent pure.

Mequiv/L



Solution ; CO_2= 1 mequiv/l

$Ca(HCO_3)_2$= 3.5-1=2.5 mequiv/l

$CaSO_4$= 5-3.5=1.5 mequiv/l

$MgSO_4$= 6-5= 1mequiv/l

Na_2SO_4= 8-6 =2 mequiv/l

Lime is used to remove carbonate hardness and magnicium non carbonate hardness while soda ash is used for permanent hardness. Castic soda is used for all types of hardness.

1) 1.0 CO_2 + 1.0CaO→ 1.0 $CaCO_3$

11) 2.5 $(Ca^{2+} + 2HCO_3)$ +2.5 CaO→ 5$CaCO_3$ +5.0 H_2O

12) 1.5$(Ca^{2+} + SO^{2-}4)$ +1.5 Na_2CO_3→ 1.5$CaCO_3$ + 1.5 $(2\ Na^{+} + SO^{2-}4)$

Second stage recarbonation is required to stabalize the water. Assume a $CaCO_3$ concentration of 40 mg/l is in the effluent water. Some part should be converted to reach the equilibrium.

0.5 $CaCO_3$ + 0.5 CO_2 + 0.5 H_2O→ 0.5 $Ca(HCO_3)_2$

Total chemical requirements are

Lime = 1+2.5 =3.5 mequiv/l

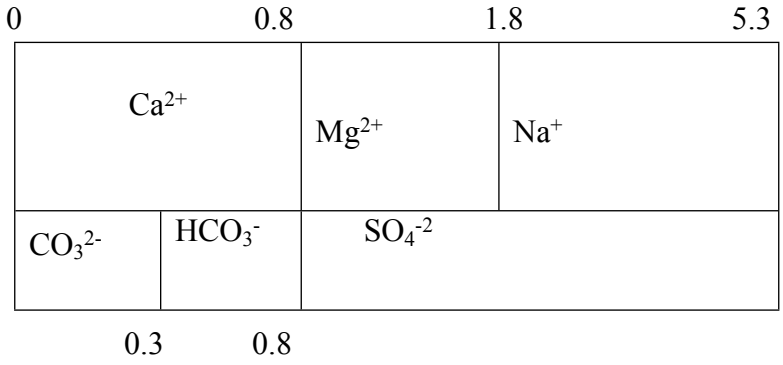
Soda ash"Na_2CO_3 = 1.5 mequiv/l

CO_2 = 0.5 mequiv/l

total calcium carbonate solids after softening (the dissolve calcium carbonate as assumed above must be substructed 40/50 = 0.8 meequiv

$CaCO_3$ =1+5.0+1.5 -0.8 = 6.7 mequiv/l

1) The bar diagram for the finished water



3) The equivalent weight of lime, carbon dioxide and soda ash is

Lime = 40 + 60 ÷ 2 = 28 mg/mequiv

Soda ash = 2(23) +12+ 3(16) ÷ 2 = 53mg/mequiv

Carbon dioxide = 12 + 2(16) ÷ 2 = 22 mg/mequiv

The daily chemical requirements are

Lime (1/0.9) 28mg/mequiv × 3.5mequiv/L ×25 ×10^6 L/d × 1kg/10^6mg = 2722 kg/d

Sada ash (1/0.85) 53mg/mequiv × 1.5mequiv/L ×25 ×10^6 L/d × 1kg/10^6mg = 2338 kg/d

Carbon dioxide 22mg/mequiv × 0.5mequiv/L ×25 ×10^6 L/d × 1kg/10^6mg = 275 kg/d

the mass of dry solids produced per day is

50mg/mequiv × 6.7mequiv/L ×25 ×10^6 L/d × 1kg/10^6mg = 8375 kg/d

CHLORIDE(CL

Inland natural water has low chlorides concentration often less than that of bicarbonates and sulphats. High concentration of chlorides in natural water is due to organic waste and animal and industrial effluents and is regarded as indicator of pollution. High concentrations are giving salty to water.

Reagents

1)potassium chromate indicator (K_2CrO_4)

Dissolve 50 g of potassium chromate in 100 ml of distilled water

2) silver nitrate solution($AgNO_3$) titrant

2.395 g in 1000 ml of distilled water

3) Hydrogen per oxide(H_2O_2)

Ready made.

Procedure

Take diluted silver nitrate($AgNO_3$) in burret and 20 ml of water sample in titrant flask. Add 2-3 drops of k_2CrO_4 indicator in water sample. Titrate it against the silver nitrate till the colour change from pale yellow to brick red.

Standardization

1ml of $AgNO_3$=0.45 mg Chloride(Cl^-)

We can calculate the required silver nitrate by following formula

to neutralize the given amount of solution if we have chloride weight

$$\text{formula} = \frac{\text{mg Chloride} \times 1000 \text{ ml}}{\text{ml sample}}$$

=mg/l

Calculation

$$Cl\ (mg/l) = \frac{\text{ml of } AgNO_3 \times N \text{ of } AgNO_3 \times Cl \text{ mass value}}{\text{ml of sample used}} \times 1000$$

SULFATES (SO_4)

Sulfate comes from several sources such as the dissolution of gypsum and other mineral deposits containing Sulfate from seawater intrusion, from the oxidation of sulfides, sulfites, and thiosulfate in well-aerated surface waters and from industrial effluents where sulfuric acids have been used in process such as tanning and pulp paper manufacturing.

Reagents

Standard solutions for sulphate

1) Potasium sulphae(K_2SO_4) =1.81g +1000 ml distilled water

2) Barrium chloride($BrCl_2$) =5g+ 500ml distilled water

Then take

$BrCl_2$=5 ml

K_2SO_4=40 ml

Total =45 ml solution which contains 500ppm SO_4 according to formula

Procedure

Take 45ml solution of barium chloride and potassium sulphate in a beaker which contain 500ppm sulphate. Half the 45 ml solution to 22.5ml which contain 250ppm sulphate,now dilute this 22.5ml solution again to 45ml,which reduces the sulphate amount to 125ppm. Repeate this process and make total five(5) solution,which have diffent milky colours indicate the amount of sulphate present in it.after that took 20ml sample and add 1ml $BrCl_2$ and compared the sample with all five standard solutions and noted coloure value matching with them or between them.

No	Location	Source	pH	Total Hardness (mg/L)	Ca Hardness (mg/L)	Alkalinity (mg/L)	Chloride (mg/L)	SO_4 (PPm)
1	Badin Zai	Kareez	7.05	188	66	140	47.15	46.875
2	Kochai Zai	Kareez	6.95	200	68	115	47.15	16
3	Wani	Kareez	6.82	184	67	225	32.26	30
4	Khut Kanda	Kareez	6.85	260	136	185	67	70
5	Khado Zai	Tank	7.01	212	116	102	37.22	62.5
6	Rukhpoor	Bore	7.16	248	132	210	39.7	25
7	Zhob city	Bore	7.15	400	264	400	101.74	93
WHO			6.5-8.5	300 mg/L	Permissible 75	250	250	250
PCRWR			6.5-8.5	<500 mg/L	Maximum 200	250	250	250

The chemical analysis of potable water; as an example, district Zhob

HEAVY METALS

The presence of heavy metals in drinking water higher than a certain concentration can cause detrimental impacts on human health. Therefore, the analysis of heavy metals in drinking water is an important parameter, and most of the studies on drinking water quality involve investigation of heavy metals. In the present study, the results of heavy metals such as Cu, Zn, Fe and Cd are compared with the safe drinking water standards.

Procedure

The heavy metals(Cd,Cu,Zn and Fe etc) can be analyzed through Electro thermal Atomic Absorption spectro meter.

IRON (FE):

Groundwater usually contains more of this mineral than surface water. Iron contents in potable water should be avoided if it exceeds the permissible limit of 0.3 mg/l and its recommended value in potable water is 0.1 mg/l. They stain clothing and plumbing fixtures, and the growth of iron bacteria causes strainers, screens to clog, and metallic conduits to rust. The appearance of a reddish brown or black precipitate in a water sample after shaking indicates, respectively, the presence of iron.

This parameter, when analyzed for different samples of district Zhob, showed the result in a range of 0.00 to 0.033mg/l. The highest value was found in Kareez water of Badin Zai, this may be because the Kareez water originates from strong mountainous region, While the minimum (zero) value was found in Kareez water of Kochai Zai Babar. The mean value is 0.01mg/l, which is lower than that of recommended value. All samples were within the permissible limit as in below table.

Analytical Result of Iron (Fe) Zhob as an example

Serial No	Location	Source	Mean mg/L	Standard Deviation	%RSD
1	Badin Zai	Kareez	0.033	0.0549	164.19
2	Kochai Zai	Kareez	0.0	0.0127	221.07
3	Wani	Kareez	0.002	0.0339	1709.3
4	Khut Kanda	Kareez	0.013	0.051	292.6
5	Khado Zai	Tank	0.008	0.027	324.29
6	Rukhpoor	Bore	0.023	0.0526	225.97
7	Z hob city	Bore	0.002	0.0349	2108.1
	WHO Permissible limit		0.3 mg/L		
	PCRWR Permissible limit		Recommended 0.1 mg/l		

CADMIUM (CD):

Cadmium is a natural, usually minor constituent of surface and groundwater. Cadmium may enter aquatic systems through weathering and erosion of soils and bedrock. Cadmium derives its toxicological properties for plants, animals and humans. Cadmium is bio persistent and, once absorbed by an organism, remains resident for many years. In humans,

long-term exposure is associated with renal dis function. High exposure can lead to obstructive lung disease and has been linked to lung cancer. The average daily intake for humans is estimated as 1µg from water.

This parameter, when analyzed for different water samples of district Zhob, showed result in the range of 0.006-0.023mg/l. The manimum value was noted for the sample of Kareez water of Kochai Zai Babar which was 0.006mg/l while the maximum value was found in Kareez water of Wani which was 0.023mg/l. The mean value of all samples was 0.017mg/l. keeping in mind that according to PCRWR, the permissible limit of Cd is 0.01mg/l. Out of seven samples only two samples were within the permissible limit of Pakistan council of research in water resources (PCRWR) while the other samples were slightly higher than this limit. According to WHO, the permissible limit is 0.003mg/l. All the samples exceeded this permissible limit, only the sample of Kareez water of Kochai Zai has value 0.006mg/l, which is near to this limit in following table.

Analytical Result of Cadmium (Cd) district Zhob as an example

Serial No	**Location**	**Source**	**Mean mg/L**	**Standard Deviation**	**%RSD**
1	Badin Zai	Kareez	0.021	0.0118	55.09
2	Kochai Zai	Kareez	0.006	0.0092	146.04
3	Wani	Kareez	0.023	0.0024	10.73
4	Khut Kanda	Kareez	0.019	0.0128	68.97
5	Khado Zai	Tank	0.02	0.003	14.67
6	Rukhpoor	Bore	0.014	0.0058	42.37
7	Zhob city	Bore	0.022	0.0103	45.73
WHO Permissible limit			0.003		
PCRWR Permissible limit			0.01		

COPPER (CU):

Copper is a metal that is naturally present in the environment, but the levels of contamination can be increased around agricultural land, near smelting facilities, and phosphate fertilizer plants. There are also significant amounts of copper released from wastewater treatment plants, which could lead to problems downstream for a community that uses this water as their source of drinking water. The most common health effects of the excessive consumption of copper bearing water would be nausea, vomiting, diarrhea,

upset stomach, and dizziness. If extreme intake of copper occurs, kidney and liver damage is possible.

This parameter, when analyzed for different samples of district Zhob, resuled in a range 0.013-0.035mg/l. The minimum value was found in the source of potable water of Kochai Zai while the maximum value was found in potable water of Khut Kanda. The mean value was recorded as 0.025mg/l. All the samples as well as the mean value were lying within the permissible limit, which is 2mg/l.

Analytical result of copper (Cu) ; district zhob as an example

Serial No	Location	Source	Mean mg/L	Standard Deviation	%RSD
1	Badin Zai	Kareez	0.032	0.0148	45.87
2	Kochai Zai	Kareez	0.013	0.0121	90.67
3	Wani	Kareez	0.021	0.0133	62.85
4	Khut Kanda	Kareez	0.035	0.101	29.09
5	Khado Zai	Tank	0.025	0.0074	30.02
6	Rukhpoor	Bore	0.023	0.0074	20.36
7	Zhob city	Bore	0.028	0.0065	23.42
WHO Permissible limit			2 mg/L		
PCRWR Permissible limit			2 mg/L		

ZINC (ZN)

Zinc is an indispensable trace element found in almost all potable water in the form of salts or organic complexes. By erosion of metals from rocks, solids however marginally soluble in water. In water the Zinc deliberation can be abundant as a result of leaching of Zinc from piping and fittings. Increased Zinc can origin eminent health difficulties such as stomach cramps, skin irritations, vomiting and nausea, and anemia, root trouble in pancreas, protein metabolism and further it can generate arteriosclerosis (WHO, 1993).

This parameter when analyzed for different samples showed the result in a range 0.00-0.011mg/l. most of the samples have zero values, the highest value was found in Zhob city water. As most samples have zero values, the related diseases were not found. All the samples were within the permissible limit, which are 3mg/l and 5mg/l respectively.

Analytical result of zinc (Zn); district Zhob as an example

Serial No	Location	Source	Mean mg/L	Standard Deviation	%RSD
1	Badin Zai	Kareez	0	0.0047	251.08
2	Kochai Zai	Kareez	0	0.0035	472.03
3	Wani	Kareez	0	0.0066	628.04
4	Khut Kanda	Kareez	0	0.0014	51.83
5	Khado Zai	Tank	0	0.003	661.36
6	Rukhpoor	Bore	0.004	0.0063	156.29
7	Zhob city	Bore	0.011	0.0022	19.35
WHO Permissible limit			3 mg/L		
PCRWR Permissible limit			5 mg/L		

NATURAL PURIFICATION IN WATER QUALITY

The water cycle driven by sunlight purifies the water in many ways. Rain, lakes, and ground water therefore tend to be relatively clean of dissolved matter and are usually drinkable in natural state.
Water is purified in nature by a number of processes. But for ease, these are categorized in two terms.
1. Physical Processes
2. Chemical Processes

PHYSICAL PROCESSES

There are four physical processes, involving forces such as gravity. Four are given as.
1. Dilution
2. Sedimentation
3. Filtration
4. Aeration

1. Dilution: it is a reduction in concentration of a pollutant when it is discharged into water. It increases as one moves away from the point of pollutant discharge. Faster water increases the rate of dilution. Fast moving streams have the ability to remove the waste up to five times more than slow moving streams.
2. Sedimentation: Settle down of suspended objects or particles in water is sedimentation. It changes as the size of objects and speed of water vary, Occurring most readily with larger objects and slow-moving water. Small sized particles may be suspended for a long period in water and covers a long distance.

3. **Filtration:** Filtering water through sand and other settled sediments to remove the suspended objects in water. Very fine objects or particles can be filtered or removed if water percolates through fine sediments.
4. **Aeration:** It is the release of gaseous impurities into air or atmosphere. Water contains a number of dissolved matters. Aeration is mostly accelerated when more water is exposed to air. It is also effective in hot and faster waters.

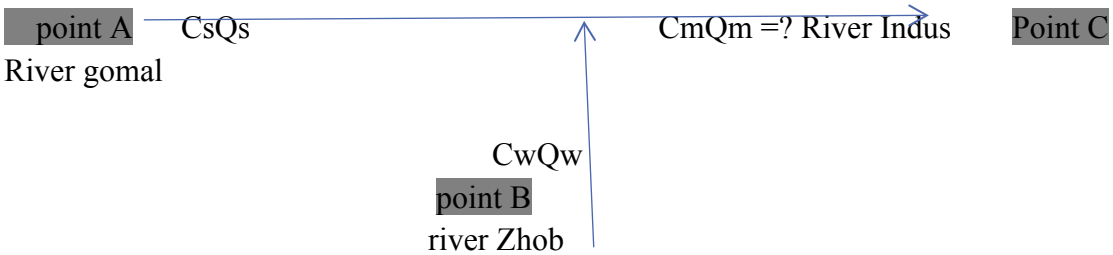
Chemical process

Purification occurs through processes such as adsorption, precipitation, oxidation, and pH buffering. Contaminants like heavy metals and organic compounds adhere to soil and clay particles, while minerals may precipitate and settle out of the water. Natural redox reactions transform harmful chemicals such as ammonia or sulfides into less toxic forms, while the buffering capacity of carbonate rocks helps stabilize the pH of water bodies.

Biological process

Microorganisms, algae, and aquatic plants play a vital role. Bacteria decompose organic matter through biodegradation, converting pollutants into harmless substances like carbon dioxide and water. Plants in wetlands absorb excess nutrients, such as nitrates and phosphates, while microbial communities living around their roots act as natural biofilters. Together, these interlinked processes ensure that water passing through natural ecosystems becomes cleaner, safer, and more balanced, illustrating nature's remarkable ability to sustain water quality without human intervention.

Q: 1 Assume the river zhob with flow rate 1500 m^3 per second having chloride in wastewater 50 mg/L at point **"A** "flowing towards river Gomal D.I khan: which have an assumable flow rate 200 m^3/S and chloride quantity 2000 mg/L at a specific starting point "**B"** due to urbanization and industrialization. Determine the concentration of chloride and flow rate at point **"A"** assuming that complete mixing has occurred.



Answer: First river zhob flow rate (Qs) = 1500 m^3/S

Chloride concentration (Cs)= 50 mg/l

Second river Gomal flow rate (Qw)=200 m^3/s

Chloride concentration (Cw) =2000 mg/l

Last point dilution (Cm) and flow rate (Qm)

Formula

Qm Cm = Qs Cs +Qw Cw

1700 Cm =1500×50 + 200×2000

1700Cm =75000+400000

Cm= 475000÷1700

Cm=279.4 mg/l

Flow rate Qm)

Qm Cm =Qs Cs +QwCw

$$Qm = \frac{Qs\,Cs + Qw\,Cw}{Cm}$$

$$Qm = \frac{1500\times50 + 200\times2000}{279.4}$$

$$Qm = \frac{75000 + 400000}{279.4}$$

Qm= 1700 meter cube/second

Numerical# 2 two factories on a riverbank have a permit to produce 300 mg/l pollutants. River has already (Cs) 50 mg/l pollutants with speed (Qs) 1500 m^3/S. The first factory has (Cw1)2000mg/l pollutants with speed (Qw1) 150 m^3/S. What will be the flow rate and dilution of first factory near second? The second factory has (Qw2) 100 m^3/S. What will be the allowed pollutants (Cw2) for second factory and also what will be the flow rate (Qm2) of river water to achieve the permissible limit of dilution (Cm2)?

Solution: after pollutants of first factory water speed is (Qm1) =?

Qm1 = Qs + Qw1

Qm1 =1500+150

Qm1= 1650 L/S

Pollutants of the first factory Cm1 =?

Cm1 Qm1 =Qw1 Cw1 + Qs Cs

Cm1 = Qw1 Cw1 $_+$ Qs Cs ÷ Qm1

Cm1 = 150×200 + 1500 × 50 ÷ 1650

Cm1= 300000+75000÷ 1650

Cm1= 227.27 mg/l

Qm2= Qm1+Qw2

=1650+100

=1750 m^3/S

And Cm2 is the final permissible limit which is 300 mg/l

Pollutants limit for factory second to achieve permissible limit

Cm2 Qm2 =Qw12Cw2 + Qm1Cm1

Qw2Cw2 = Cm2 Qm2 - Qm1Cm1

Cw2 = Cm2 Qm2 - Qm1Cm1 ÷ Qw2

Cw2 = (1750) (300) – (1650) (227.27) ÷ 100

Cw2 = 525000 – 374995.5 ÷ 100

=150004.5 ÷100

=1500mg/L SO second factory is allowed to produce such amount of pollutants.

WATER POLLUTION

"The presence of deleterious matter in such quantities to make the water unsuitable for its designated use." In Scientific sense, "water pollution is a distortion of the aquatic ecosystem; hence water pollution is such a change which 'adversely affect the aquatic ecosystem in terms of the living organism, Oxygen content, the presence of toxins and so on."

pollution of water means "a change from normal state (rather than a pure water, for ideally unpolluted water is misconception) of water by human activities in such a manner to prevent it from being used for the purposes thought as normal". Normal areas of use include domestic, agricultural, Industrial, Fish, and other aquatic life and wildlife including recreation and aesthetics.

The water (Prevention and control of pollution) act 1974 makes a legal definition of water pollution as "Such contamination of water or such alteration of the physical, chemical, or Biological properties of water or such discharge of any sewage or trade effluent or any other liquid, gaseous or solid substance into water as may, or is likely to create a nuisance or render such water harmful or injurious to public health or safety or to domestic, commercial, industrial, agricultural or other legitimate uses or to the life and health of animals or aquatic organism."

There is a difference in contamination and pollution. Pollution is agents or activities producing damage in the environment damage the entire ecosystem, While Contamination supported by the environment without stopping the general chemical cycles and life cycles.

So, Contaminated water is defined as "Water that is rendered un-useable for drinking."

WASTE WATER POLLUTANTS COMPOSITION AND SOURCES

The composition varies depending on the source and local practices, but overall, wastewater reflects a combination of organic pollutants, inorganic compounds, and microbial contaminants that require proper treatment before discharge or reuse. Wastewater is generated from multiple sources such as domestic, industrial, agricultural, commercial, and stormwater runs off. Domestic wastewater originates from households, including kitchens, bathrooms, and toilets, and mainly contains organic matter, soap, detergents, and pathogens. Industrial wastewater is produced by factories and manufacturing units, often containing toxic chemicals, oils, dyes, heavy metals, and acids. Agricultural sources include runoff from farms that carry fertilizers, pesticides, and animal waste rich in nutrients and organic pollutants. Commercial and institutional wastewater comes from places like restaurants, hospitals, and offices, containing grease, cleaning agents, and food residues. Stormwater runs off from roads and urban areas collect oil, sediments, plastics, and debris. Altogether, these sources introduce a wide range of pollutants such as organic waste, nutrients (nitrogen and phosphorus), pathogens, suspended solids, and hazardous chemicals into the environment, making wastewater treatment essential for protecting public health and ecosystems.

WASTE WATER TREATMENT

For wastewater treatment, the following methods and related equipment's are used:

Preliminary treatment

(i) Screening: this is the process through which large objects such as rages, bones and sticks etc. with size of 1-4 meters.

(ii) Grit removal: grit is some small inorganic substances with specific weight and densities. This can be removed by small chambers and settling chambers.

9) Primary treatment

The purpose of this treatment is the removal of suspended solids of both types i.e organic and inorganic.

Sedimentation: sedimentation is carried out in a settling tank. The water is stored for some days. The suspended solids settled out by their relative density. About 90% of inorganic matter and 40% of organic matter is settled. So, a significant portion of organic matter (BOD) is purified.

Sedimentation aid: there are two techniques which improve the sedimentation process are called sedimentation aids, which are two types:

(i) Mechanical flocculation:
The wastewater passed through a tank with a detention of thirty (30) minutes and filled with paddles at a peripheral speed of 0.43 m/s. under this gentle stirring, the finely divided suspended solids coalesce into large particles and settle out. Specialized equipment such as Clariflocculator is also available. Wherein flocculating chamber is a part of sedimentation tank.

(ii) Chemical coagulation:

Another sediment aid is coagulation in water and wastewater treatment. Coagulants form a flock (flocculant precipitate) to settle the suspended organic solids. The most used coagulants are Alum ($Al_2(SO_4)_3$. 18 H_2O), hydrated lime and ferric acid etc. The coagulants reduce the repulsive and increase attractive forces between particles to combine. Coagulants is the most effective and economical means to remove impurities.

10) Secondary treatment

Secondary treatment is the removal of organic dissolve and colloidal solids by using microorganisms in a specified treatment methods. These processes may be aerobic or anaerobic.

In aerobic process, bacteria and other microbes use organic matter of wastewater as food. This process is given in a sequence below:

a) Coagulation and flocculation of colloidal matter.
b) Oxidation of organic matter to carbon dioxide (CO_2).
c) Degradation of organic matter as nitrogenous matter to ammonia, which is then converted into nitrite and finally to nitrate. Thus, secondary reduce biological oxygen Demond (BOD). Aerobic processes are aerated lagoons, trickling filters, activated sludge, Oxygen ditch and oxygen pound. They collect dissolved organic matter and use microorganisms such as

bacteria to convert or degrade them into carbon dioxide (CO_2), water, nitrite, nitrate and sulphates. This is called humus, which combines with sediments of primary treatment is called sludge, which is further treated in aerobic digestion. All organic matter with some exceptions such as Hydrocarbons and Ether are treated with aerobic process. Complex cell tissues and protein materials are also synthesized during this process. Phenols can be destroyed by special types of microorganisms of prolonged adopted periods.

Under anaerobic conditions using some anaerobic microbes to convert complex organics into simpler one e.g. hydrolyte. They convert complex organics into organic acids and alcohols. Then these are converted into carbon dioxide and Methane by a special type of methane bacteria. This converts all organic matter with some exceptions such as lignin and some mineral oils. The process is not expensive, but the final stage of this process is unsatisfactory because sludges have color, odor and higher residual BOD. The aerobic processes are as follows:

i. Aerated lagoons

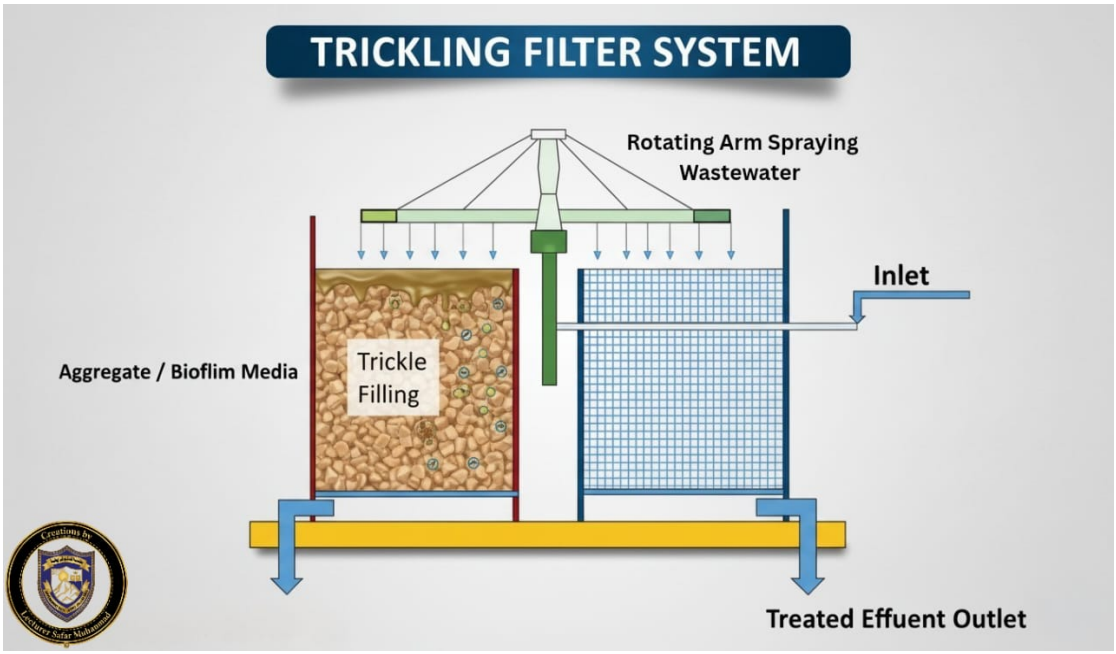
These are ponds with depths of 3-5 centimeters and lined with polythene or rubber. The effluents from primary treatment process are collected in these tanks and are aerated with mechanical devices for 2-6 days. Slow flocculation and settlement occur. A basic difference from oxidation pound is that mechanical aeration is provided. With best operation about 90% BOD is removed. The major disadvantage is the large space requirement and bacterial contamination of lagoon.

ii. Trickling filters

Trickling filters are the bedmate by hard medium such as brock stones, coal, cock and PVC etc. the wastewater from primary treatment is sprinkled uniformly on this bed by nozzles. The amount of dissolve organics will increase with time and form biofilms, which is also called “zoogloea” on the surface of bed used as filter. These biofilms have microorganisms with their food. When these biofilms are bigger in size detached from filter and because of gravity settling tank and forced to sludge(humus) digestion unit. Which will further be treated in anaerobic digestion along with primary treatment sedimentation. About 85-90% BOD removal is possible through this process.

Aeration is provided beneath and inside filter medium so called aerobic but also anaerobic and facultative bacteria and their function is also found. For large industrial processes, plastic is used as a bed because of economic benefits and covers more space.

Disadvantages: the disadvantages of this process include the cost of construction and need for dust ventilation for the under-drainage system. Trickling filters are used efficiently for the treatment of industrial wastes from dairy, distillery, brewery, cannery, slaughterhouses and poultry processing industries.



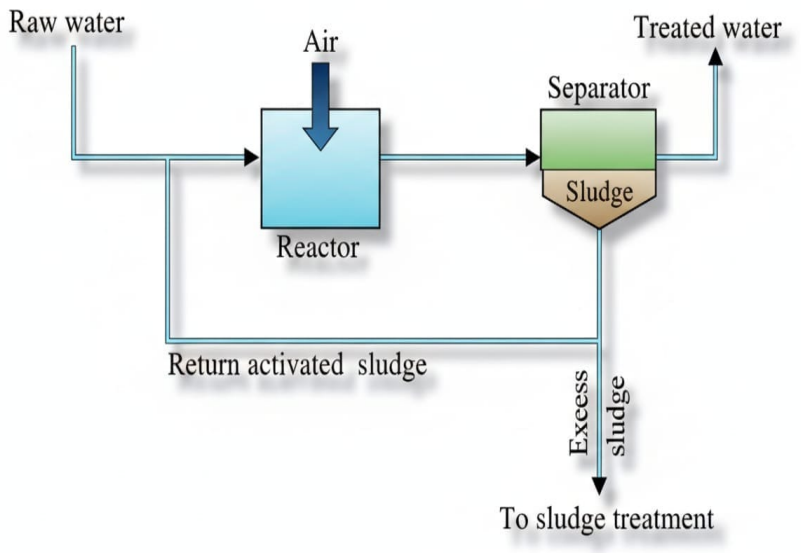
iii. <u>Activated sludge</u>

In this process microorganisms grow of the floc of dissolve organic solids. As the floc increases in size, the microorganisms present use this for food and degrade this to carbon dioxide and water.

This process contains many active microorganisms, in way the process is called activated sludge. The oxygen provided mechanically or naturally for microbes to degrade organic matter.

The wastewater from primary treatment in activated sludge tank, in which flocculation occurs about 2-6 hours' time is required for sewage treatment and for industrial sewage treatment, 6-24 hours' time is required.

As this is an aerobic process, about 0.5ppm oxygen is required on a permanent basis. Essential nutrients such as "nitrogen and phosphorous" are provided for the growth of microorganisms in activated sludge. Other nutrients such as potassium, magnesium, and calcium are already present in wastewater or in sludge. The important factors for efficient activated sludge are P^H, temperature and oxidation-reduction potential. The optimum P^H for this process is 6.5-9. About 95% BOD removal is possible through this process. The disadvantage of this process is high maintenance cost. This process is used in food processing, sugar, textile processing and antibiotics manufacturing industries etc.



iv. Oxidation ditch

This process is carried out in a shallow tank 1-3 meter deep. The interlining in medium is plastic or such other medium. The aeration is through natural or mechanical process. This process is carried out in low wastewater industries. For wastewater, the settling time of dissolve organics is 12-24 hours and for solids is 20-30 days. This process is cost-effective and also simple to operate.

v. Oxidation pound:

The basic difference from aerated lagoons is that this operates by natural aeration. This pound is very shallow from 1.5-2 meters in depth, for the purpose that light can penetrate inside. The algae use sunlight and carbon dioxide for photosynthesis. Carbon dioxide comes from the degradation of dissolved organic matter. The algae give oxygen in return. Nutrients are adding manually to enhance the growth of algae for oxygen production which is used by bacteria to degrade waste and purify water indirectly. Although the process is considered aerobic, which produce carbon dioxide and water as a byproduct while anaerobic and facultative bacteria are also involved. An anaerobic process produces ammonia, methane and carbon dioxides as byproducts by the degradation of waste. This process is efficient because of its simplicity and cheapness. This process can also be used for all types of waste, and every degree of purification is achieved.

vi. Anaerobic digestion

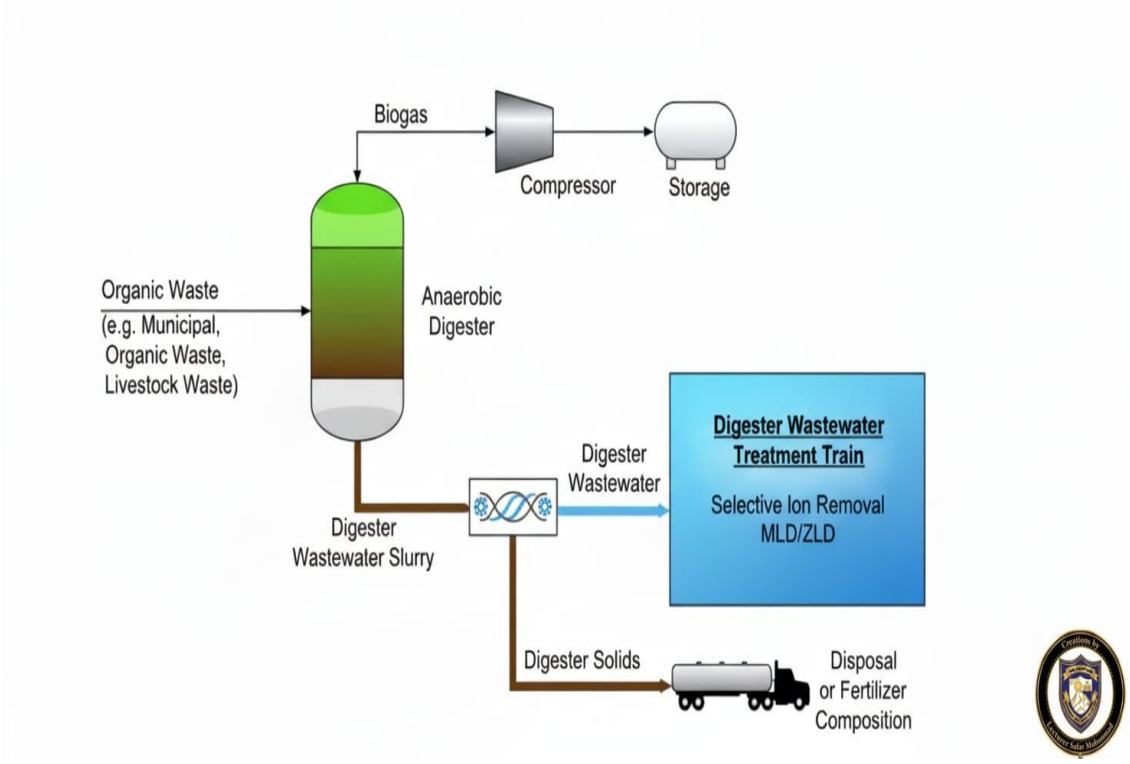
This process is mainly used for sludge digestion not for wastewater. Sludge the final residue from the primary sedimentation tank and humus tank of the secondary treatment. This is the fermentation (without oxygen and anaerobic bacteria) of sludge for a long time, almost thirty (30) days with specific temperature (35 degrees Celsius) and pH (7-8). This process is always accelerated at higher temperatures. Methane, ammonia and carbon dioxides are the end products.

This process has many advantages as below:

- Reduction of waste volume by about 65%.
- This digested sludge is safer to be used as manure than the undigested sludge.
- The digester gas (mostly methane) obtained has good calorific values (26 MJ/m^3 about 700 BTU/ft^3) can be used as a fuel to provide the heat required to warm the digestion tanks.
- In large installations, the digester gases can be used for power generation.
- Although anaerobic digestion is a slow process, it is useful for the treatment of small quantities of waste. As the operating and maintenance costs are lower. That is why some liquid waste containing soluble organics from dairy, slaughterhouses, and paper industries have been economically and effectively treated by this process.

Sludge treatment and disposal

sludge from wastewater containing about 95% water. This needs to be dewatered, so drying beds, filter processes or vacuum filters are being used. The de-watered sludge, after chlorination can be sent for ultimate disposal by solid waste departments. The different ultimate disposals include sanitary landfilling, incineration, open dumping in selected area and in sea, or utilizing as a low-grade fertilizer.



11) Tertiary treatment

Tertiary treatment is the final treatment, is the polishing of effluents from the secondary treatment processes. To improve its final quality, the following major objectives are under consideration.

a) Removal of final suspended solids
b) Removal of bacteria
c) Removal of dissolved inorganic solids
d) removal of final traces of organic matter

removal of suspended solids can be achieved with the help of micro-strainers and sand-filters.

Removal of bacteria, particularly of faecal origin, can be achieved by retaining the effluents from secondary biological treatment plants in maturation ponds or lagoons for specific periods of time. Three or four lagoons are arranged in series give an excellent final effluent with very low BOD and low suspended solids. The final effluents are chlorinated if necessary.

Removal of dissolved inorganic solids is the most major problem with waste waters from industries such as fertilizers, textile processing, tannery and electroplating. Depending upon the required quality of the final effluent and the cost of treatment that can be afforded in a given situation, following treatment methods are commonly used.

- **Evaporation:** energy consuming and hence high expensive process. It is only used when the recovered solids or the concentrated solutions are reused. E.g. some electroplating wastes, this method is also limited to heavy concentration of radio-active liquid wastes or any chemicals which are not recoverable by any other method.
- **Ion-exchange:** this is the de-mineralization of wastewater, a widely used method. It is used for obtaining de-ionized water use in high-pressure boilers. Now this method is extended to wastewater treatment for the recovery and removal of toxic materials from wastewater such as in the electroplating industry. It may recover chromium, nickel and other heavy metals and recover phosphate and H_2SO_4.
- **Adsorption:** adsorption by activated carbon is advantageous to remove small quantities of organic contaminants from wastewater as the final removal of tertiary treatment as in option(d). Special types of absorbents are also commercially available to remove toxic heavy metals from industrial wastewater. Activated carbon is used for the treatment of pesticides such as DDT and carbamate insecticides.
  Adsorption is the most useful process using many materials as absorbents such as activated carbon, peat moss, brown coal and other cellulose materials in wastewater treatment for the removal of refractory organic, toxic metals and colors etc.

GLOSSARY

A

Agenda21: Agenda 21 is a global action plan adopted at the 1992 Earth Summit to promote sustainable development and address environmental, social, and economic issues for the 21st century.

Advanced informed agreement: A procedure under the Cartagena Protocol (COP) that ensures countries are informed and give consent before importing living modified organisms (LMOs) that may affect biodiversity or human health.

Air quality index: The Air Quality Index (AQI) is a numerical scale that measures and indicates the level of air pollution in a specific area, showing how clean or polluted the air is and its potential effects on human health.

Alzheimer's: Alzheimer's disease is a progressive brain disorder that causes memory loss, confusion, and difficulty in thinking and performing daily activities.

Aquariums: An aquarium is a transparent tank or container filled with water used to keep and display fish, aquatic plants, and other water-dwelling organisms for study, decoration, or recreation.

Animal unit: A cow with his calf (450 kg) which eats 9.1 kg food for 24 hours is called an animal unit. Animal units are mostly used in natural resource management.

B

Bauxite: Bauxite is the primary ore of aluminum, composed mainly of aluminum hydroxide minerals mixed with iron oxides and silica**.**

Biosafety clearing house: The Biosafety Clearing-House is an international information system that helps countries share and access data related to the safe handling, transfer, and use of living modified organisms (LMOs) under the Cartagena Protocol on Biosafety.

Blue carbon: Blue carbon refers to carbon captured and stored by coastal and marine ecosystems such as mangroves, seagrasses, and salt marshes.

Brown haze: Nitrogen dioxide ($NO_{2)}$ is reddish brown gas, sometimes called brown haze in pollution context, especially in photochemical smog.

Brown carbon: Brown carbon is a type of atmospheric aerosol made up of organic particles that absorb sunlight, contributing to climate warming and air pollution.

C

Cap and trade: Cap and trade is a market-based system that limits (caps) total greenhouse gas emissions and allows companies to buy and sell emission permits (trade) to meet their reduction targets efficiently.

Carbon capture, usage: Carbon Capture and Usage is a process of capturing carbon dioxide (CO_2) emissions from industrial sources and reusing them to produce useful products like fuels, chemicals, or building materials.

Carbon credit: Emission reduction units (ERUs) also called carbon credit is the reduction in carbon emissions of one ton (1000kg) carbon or CO2 or any other gas equivalent to one ton carbon in the atmosphere.

Carbon footprint: A carbon footprint is the total amount of greenhouse gases, especially carbon dioxide, released into the atmosphere by human activities directly or indirectly.

Carbon sink: A carbon sink is a natural or artificial system that absorbs and stores more carbon dioxide from the atmosphere than it releases, such as forests, oceans, and soil.

Carbon tax This tax is based on the amount of carbon contained in fuel such as coal, etc. The aim of this tax is to cause less fossil fuel use and hopefully cause an incentive to use other sources of energy.

Carbon trust: An organization that helps businesses and governments reduce carbon emissions and promote low-carbon technologies for sustainable development.

Carbon offsetting: Carbon offsets are credits for reductions in greenhouse gas emissions made at another location, such as wind farms and solar panels which create renewable energy and reduce the need for fossil-fuel powered energy.

Carcinogenic: It refers to any substance, radiation, or agent that can lead to the development of cancer in living tissues. For example, tobacco smoke and asbestos are known carcinogenic materials.

Cartagena protocol: The Cartagena protocol on biosafety is an international agreement under the convention on biological diversity (CBD. Biosafety refers to the need to protect human health and the environment from the possible adverse effects of the products of modern biotechnology.

Climate Promise - II (Pakistan): a UNDP project to help Pakistan respond to climate change by strengthening national and sub-national institutions, integrating climate policies, implementing its Nationally Determined Contributions (NDCs), promoting green jobs especially among vulnerable groups, and developing climate-resilient plans and regulations

Central pollution control board (CPCB): Central Pollution Control Board (CPCB) is a national body in India that monitors, controls, and advises on pollution prevention and environmental protection under the Ministry of Environment, Forest and Climate Change.

chapman cycle: The ozone layer is created when ultraviolet rays react with oxygen molecules (O2) to create ozone (O3) and atomic oxygen (O).

chromite: the principal ore of chromium, a brownish-black oxide of chromium and iron.
convention on biodiversity: CBD (Convention on Biological Diversity) is an international agreement aimed at conserving biodiversity, using it sustainably, and sharing its benefits fairly.
Coriolis force: Coriolis force is an apparent force caused by Earth's rotation that makes moving objects, like winds and ocean currents, curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere**.**

cryopreservation: cryopreservation is the process of preserving cells, tissues, or other biological materials at very low temperatures to stop all biological activity and keep them viable for future use.

Climax community: Climax community is associated with a particular climate and in a state of dynamic equilibrium with climate. This is the mature state of ecological succession.

Coral reef: A coral reef is a large underwater structure made up of colonies of tiny living organisms called coral polyps that secrete calcium carbonate to form a hard skeleton.

Coral rescue initiative (CRI): The Coral Rescue Initiative is a global program that aims to protect and restore coral reefs threatened by climate change by safeguarding resilient species and creating refuge sites for future reef recovery**.**

community: Groups of individuals of the same or different species interacting with their physical environment making a community**.**

D

Dew: Dew is the moisture that forms as water droplets on cool surfaces, such as grass or leaves, when air containing water vapor cools to its dew point temperature, usually during the night or early morning.

Dewpoint: The dew point is the temperature at which the air's capacity to hold water is reached, causing condensation to occur. The Dew point is the temperature at which the water vapors in a sample of air, condenses into liquid water at the same rate at which it evaporates.

Dimethyl sulfide (DMS):

Dobson unit: A Dobson Unit (DU) is a measure used to describe the total amount of ozone in a column of the atmosphere. One Dobson Unit equals the amount of ozone that would form a layer 0.01 millimeters thick at standard temperature and pressure (STP).

E

Ecological footprint: Ecological footprint is a measure of the amount of land and resources needed to support a person or population's lifestyle, including the resources they use and the waste they produce.

Electromagnetic spectrum: The electromagnetic spectrum is the full range of all types of electromagnetic radiation, from radio waves to gamma rays, arranged according to their wavelength or frequency.

Estuaries: Coastal bays, river mouths and tidal marshes form the estuaries. In estuaries, fresh water from rivers meets ocean brackish water and the two are mixed by action of tides.

Exclusive economic zone: An Exclusive Economic Zone is the sea area extending up to 200 nautical miles from a country's coast, where the state has special rights to explore, use, and manage marine resources.

F

Frost: on contrast of dew, when the temperature is low enough, the dew takes the form of ice, this is called frost.

Fog: Fog is a thick cloud of tiny water droplets suspended near the ground that reduces visibility.

Food and agriculture organization (FAO): The FAO is a United Nations agency that works to improve food security, fight hunger, and promote sustainable agriculture worldwide.

G

Game reserves: Game reserves are large areas of land where wild animals are hunted in a controlled way for sports.

Gene bank: A gene bank is a facility that preserves the genetic material of plants, animals, or microorganisms for future use, mainly through seeds, tissues, or DNA storage.

Global fund for coral reefs: The Global Fund for Coral Reefs is a public–private partnership that finances and supports projects aimed at protecting, restoring, and sustainably managing coral reef ecosystems around the world.

Global coral reef alliance: The Global Coral Reef Alliance is a non-profit organization that works to protect and restore coral reefs using science-based methods and community partnerships.

Global environment facility (GEF): The Global Environment Facility is an international partnership that provides funding to address global environmental issues, such as climate change, biodiversity loss, and pollution.

Global stock take: Global Stock take is a process under the Paris Agreement that assesses the world's collective progress toward meeting climate goals, conducted every five years to guide future actions on climate change.

Global warming potential: Heat absorbed by 1kg carbon or equivalent heat absorbed by any quantity of any gas is called global warming potential.

1kg CO_2 =0.00001 Kg (CH_4)

1kg CO_2=0.0000 Kg(N_2O)

1Kg CO_2=0.00000055 Kg (SF_6)

Greenhouse gases: Greenhouse gases are gases in the atmosphere, such as carbon dioxide, methane, and water vapor, that trap heat and keep the Earth's surface warm.

Gypsum: Gypsum is a soft mineral made of calcium sulfate dehydrate ($CaSO_4 \cdot 2H_2O$), commonly used in construction materials like plaster and cement, and in agriculture as a soil conditioner.

H

Hetero sphere: A zone of the atmosphere where there is no uniform distribution of gases.

I

Indus river dolphin: The Indus River Dolphin is an endangered freshwater dolphin found only in the Indus River of Pakistan, known for its poor eyesight and use of echolocation to navigate **and** hunt**.**

Infra-red (IR): Infra-red is a type of electromagnetic radiation with wavelengths longer than visible light, commonly used in remote controls, thermal imaging, and heat detection**.**

IPCC: The Intergovernmental Panel on Climate Change (IPCC) is a UN body that evaluates scientific research on climate change, its impacts, and possible solutions for policymakers worldwide.

IQ Air: IQ Air is a global air quality organization that provides real-time air pollution data and develops air purifiers and monitoring technologies to improve indoor and outdoor air quality.

IUCN: The International Union for Conservation of Nature (IUCN) is a global organization that works to conserve nature, protect biodiversity, and maintain the Red List of Threatened Species.

J

Joule Thomson affect: when a highly pressurized gas is allowed to expand, it cools down. Our troposphere also follows the same law.

K

Kigali amendment: The Kigali Amendment is the most recent international agreement to the Montreal Protocol that aims to phase down hydrofluorocarbons (HFCs), which are powerful greenhouse gases contributing to climate change.

L

Limestone: Limestone is a sedimentary rock mainly composed of calcium carbonate ($CaCO_3$), usually in the form of the mineral calcite or aragonite.

Living modified organisms (LMOs): LMO**s** are organisms whose genetic material has been altered using modern biotechnology to exhibit new traits not found naturally.

M

Mackerel: Mackerel is a type of fast-swimming, oily fish found in both tropical and temperate seas. It is known for its shiny, striped body and is commonly used as food because it is rich in omega-3 fatty acids and protein.

Manganese: Manganese is a chemical element (symbol Mn) and a metal found in the Earth's crust. It is used in making steel, batteries, and chemicals, and is also an essential nutrient for plants and humans in small amounts.

Mangroves: mangroves are coastal natural forests which play a key role in the protection of costs from tidal surges and home to much biodiversity.

Methyl cyclohexane (MCH): most recent alternative of ozone depleting substances, which is organic in nature and degradable. It's less harmful to ozone depletion as compared to CFCs, HFCs and PFCs.

Mid-century strategies: Mid-Century Strategies (MCS) are long-term, low greenhouse gas emission development strategies that countries prepare under the Paris Agreement, building on commitments from the Marrakech Accords adopted at COP7 in 2001.

Mist: Mist consists of very fine microscopic, condensed water droplets. These are held in suspension in the air because of their small size. The visibility is obscure but still exceeds one (1) km.

N

NEPRA: NEPRA is the National Electric Power Regulatory Authority of Pakistan that regulates the generation, transmission, and distribution of electric power to ensure reliable and affordable electricity.

NDCs: NDC**s** are climate action plans submitted by countries under the Paris Agreement, outlining their targets for reducing greenhouse gas emissions and adapting to climate change.

O

OECD: The OECD is an international organization that promotes economic growth, trade, and sustainable development among its member countries.

Orphan issue: The Orphan Issue refers to certain unresolved or unaddressed topics that were left out or not clearly assigned to any specific body or mechanism during the negotiations of the Marrakech Accords and later under the Paris Agreement.

Overgrazing: Overgrazing occurs when animals graze vegetation faster than it can naturally regrow, leading to land degradation.

P

Pakistan Maritime security agency: The Pakistan Maritime Security Agency (PMSA) is a law enforcement and search-and-rescue agency responsible for protecting Pakistan's maritime interests and enforcing national and international maritime laws.

Pakistan fisheries development authority: The Pakistan Fisheries Development Authority (PFDA) is a government organization responsible for the development, management, and promotion of fisheries and aquaculture in Pakistan.

PCSIR: The Pakistan Council of Scientific and Industrial Research (PCSIR) is a government research organization that promotes scientific and industrial development in Pakistan through research, innovation, and technology transfer.

PCRWR: The Pakistan Council of Research in Water Resources (PCRWR) is a government organization responsible for conducting research, development, and management of Pakistan's water resources.

Photochemical smog: a smog induced by light when atmosphere is laden by heavy pollutants especially oxides of nitrogen, Ozone and other radicals.

Pioneer community: The first plant to colonize an area is called the pioneer community**.**

Pneumoconiosis: Pneumoconiosis is a lung disease caused by inhaling dust particles, especially in workplaces such as mines or construction sites.

Polluter pay principal: The Polluter Pays Principle (PPP) means that those who cause pollution are responsible for paying the costs of managing and reducing it to prevent environmental damage.

Preliminary scrutiny: Preliminary scrutiny means the initial examination or review of documents, applications, or proposals to check their completeness, accuracy, and eligibility before detailed evaluation.

Pulmonary fibrosis: is a chronic and progressive lung disease in which the lung tissue becomes thickened, stiff, and scarred (fibrotic). This scarring makes it difficult for the lungs to work properly, reducing their ability to transfer oxygen into the bloodstream. Common symptoms include shortness of breath, dry cough, fatigue, and gradual weight loss. The condition can be caused by long-term exposure to environmental pollutants.

Pyritic Sulphur: Pyritic Sulphur is the form of Sulphur chemically bound in pyrite (FeS_2), a common iron sulphide mineral found in coal and rocks.

Q……

R

Recharge Pakistan: Recharge Pakistan is a national climate resilience project aimed at enhancing water storage, groundwater recharge, and ecosystem restoration to reduce the impacts of floods and droughts.

Ramsar site: Ramsar sites, also called wetlands are the sites which are biodiversity hotspots demarcated in Ramsar convention for special conservation.

Reference period: A reference period is a specific time frame used for collecting, comparing, or analyzing data in studies, reports, or statistics.

S

Seed bank: A seed bank is a facility that stores and preserves seeds of various plant species to protect genetic diversity and ensure future plant regeneration**.**

Shrimp: Shrimp are small marine or freshwater crustaceans with elongated bodies and primarily used as an important seafood source worldwide.

Smog: the combination of smoke or pollutants with moisture in the atmosphere forms smog. This is atmospheric pollution and has disastrous consequences.

Snow leopard: The snow leopard (Panthera uncia) is a rare and endangered big cat found in the mountainous regions of northern Pakistan, including Gilgit-Baltistan, Chitral, and Hunza**.**

Skeletal fluorosis is a chronic bone disorder that develops from prolonged exposure to high levels of fluoride, usually through drinking water, food, or industrial emissions. The excess fluoride accumulates in bones and joints, leading to increased bone density, stiffness, pain, and limited joint movements.

T

Ten billion tree Tsunami (TBTT): The Ten Billion Tree Tsunami (TBTT) is a large-scale afforestation and reforestation project launched by the Government of Pakistan to combat climate change, deforestation, and environmental degradation.

The earth charter: The Earth Charter is an international declaration of ethical principles that promotes sustainability, peace, and respect for all life on Earth**.**

U

Ultraviolet (UV): Ultraviolet (UV) is a type of electromagnetic radiation with wavelengths shorter than visible light but longer than X-rays.

UNCCD: The UN Convention to Combat Desertification (UNCCD) is an international treaty aimed at preventing and reversing land degradation and desertification, particularly in arid, semi-arid, and dry sub-humid areas.

UNEP: UNEP is the United Nations Environment Programme, responsible for coordinating the UN's environmental activities and promoting sustainable development worldwide.

UNESCO: UNESCO is a specialized agency of the United Nations that promotes education, science, culture, and communication to foster peace and sustainable development worldwide.

UN decade of ecological restoration: The UN Decade on Ecosystem Restoration is a global initiative aimed at preventing, halting, and reversing the degradation of ecosystems to combat climate change and biodiversity loss.

V

Visible light: Visible light is the portion of the electromagnetic spectrum that can be detected by the human eye, allowing us to see colors.

W

WHO: The World Health Organization (WHO) is a specialized agency of the United Nations responsible for public health, disease prevention, and global health coordination.

WWF: The Worldwide Fund for Nature (WWF) is an international non-governmental organization focused on conservation of nature, biodiversity, and sustainable use of natural resources.

X……

Y……

Z

Zhob: Zhob District, locating in the northwestern part of Balochistan, Pakistan, is a mountainous region near the Afghanistan border. Its headquarters is Zhob city, and the district experiences a semi-arid climate with cold winters and mild summers. The local economy relies on agriculture, livestock, and small-scale trade, while the area is also rich in cultural and historical heritage. Zhob plays an important role in regional connectivity and trade due to its strategic location.

References

- Peavy, H.S. Rowe, D.R & Tchobanoglous, G. (1985). environmental engineering. McGraw-Hill book company.
- Dara, S.S. & Mishra, D.D. (2006). A textbook of environmental chemistry and pollution control; with energy Ethics and society) (reprint ed.). S Chand company LTD.
- Miller, G., & Spool man, S.E. (2013). environmental science (14th ed.). Cengage.
- Government of Pakistan. (1997). *Pakistan environmental protection act, 1997(Act No.XXXIV of 1997).* Islamabad: Government of Pakistan
- Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the IPCC* (P. R. Shukla et al., Eds.). Cambridge University Press / IPCC. https://www.ipcc.ch/report/ar6/wg3/ IPCC
- International Energy Agency. (2023). *Net zero roadmap: A global pathway to keep the 1.5 °C goal in reach (2023 update)*. IEA. https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-c-goal-in-reach IEA
- United Nations Environment Programme. (2024). *The emissions gap report 2024*. UNEP. https://www.unep.org/resources/emissions-gap-report-2024 UNEP - UN Environment Programme
- United Nations Framework Convention on Climate Change. (2023). *Outcome of the first global stocktake*. UNFCCC. https://unfccc.int/topics/global-stocktake/outcome-of-the-first-global-stocktak
- Lohani, B. N., Evans, J. W., Everitt, R. R., Ludwig, H., Carpenter, R. A., & Tu, S.-L. (1997). *Environmental impact assessment for developing countries in Asia: Volume 1 – Overview.* Asian Development Bank.
- Ministry of Climate Change. (2012). National climate change policy. Https://mocc.gov.pk
- Government of Pakistan: Ministry of Climate Change. (october,2021). national climate change policy. Https://mocc.gov.pk
- Ministry of Climate Change. Pakistan climate change act (April,2017) ministry of climate change. Islamabad April 3,2017.
- Department of commerce: united states of America (2014, January) Renewable energy of Pakistan. International trade administration. https://www.trade.gov/country-commercial-guides/pakistan-renewable-energy.
- The Balochistan environmental protection agency. (2020) review-of-IEE-and-EIA-regulations. https://bepa.gob.pk-
- Enviro Safe consultants. (2025, march26). Environmental impacts assessment report. http://envirosafe.pk
- Federal environmental protection agency of Pakistan. (1997, November). Guidelines for the preparation and review of environmental reports.
- Pakistan environmental protection agency. (2020). review of IEE and EIA regulations. .https://mocc.gov.pk.
- Government of Pakistan, ministry of environment. (2010, jan). national land policy.

- National weather service of United states. (2025, july1). Clouds development www.weather.gov
- Lutgens, F.K., Tarbuck, E.J. Dennis, T. (2016). The atmosphere: Introduction to meteorology. Pearson.
- Rodriguez, A. (1994). Rangeland Production Systems in Balochistan, Pakistan. Rangelands.
- Botkin, D.B.& Keller, E.A. (2011, January,5). environmental science: earth as a living planet (9th ed.). John Wiley and sons.
- Shankar IAS Academy (2018). Environment (6th revised edition). www.shankariasacademy.com
- Mohan, V. (2023, November 14). By 2030, *world needs to cut emission by 43%: UN report -massively off track to limiting warming to 1. 5˚C*.UN chief Guterres. The times of India.
- Khan, M.A.A. (2025, May 13) *climate war*. Dawn https://www.dawn.com
- Mirda, R. (2022, august15). *Climate change could lead to a loss of 4 percent of European GDP by 2030*. Swechha News. https://www.swechha.in/
- Alan C. Don, D, R & Malcolm. (2000). Water Supply (edition 5th). Tokyo, japan: Published.
- European Commission, Joint Research Centre. (2025). ghg emissions of all world countries – 2025 report. Publications Office of the European Union. https://edgar.jrc.ec.europa.eu/report_2025
- International Energy Agency. (2025). global energy and co_2 status report 2025. IEA. https://www.iea.org/reports/global-energy-and-co2-status-report-2025
- United Nations Environment Programme. (2024). EMISSIONS GAP REPORT 2024. UNEP. https://www.unep.org/resources/emissions-gap-report-2024
- Anwar,k. Amir,H, M. Amir,W. Shazmeen,Z and Ghulam,M.(2011). Qualitative and quantitative analysis of drinking water samples of different localities. International journal of the physical sciences, 6(33):7480-7489.
- Basavaraja. (2011*). Analysis of Water Quality Using Physico-Chemical Parameters . Global Journal of Science Frontier Research, Volume 5*, PP 89-92 .
- Government of Baluchistan. (2011). District development profile, 2011. Published by Planning & Development Department Provincial Office Baluchistan, Quetta and United Nations Children's Fund. P-10.
- Irrigation department Balochistan (2016*). Baluchistan Integrated Water Resources Management and Development Project*. http://balochistan.gov.pk

- Government of Pakistan. (2007). *Housing, Water supply, Sanitation*.
- Gurmessa, O, E. (2015). Investigation of drinking water quality from source to point source distribution. Adidas Ababa institute of technology, school of graduate studies, Ethiopia.

- Pakistan council of research in water resources. (2007). Water quality status of Pakistan: national water quality monitoring program. (5th Monitoring Report). pcrwr@isb.comsats.net.pk.
- Saddozai & Shagufta.(2015). *Water Pollution in Balochistan Province of Pakistan. International Journal of Engineering and Applied Sciences (IJEAS), volume-2*(6).
- Sadiq, M. Shahid I, D. Abdul, L. Muhammad, S. (2013). Water resources and new remains of Eocene mammals of Baluchistan Province, Pakistan: Geological Survey of Pakistan.
- Safoora, K. Muhammad, K, .Shaquffa, S. Imran, T. Ferhat, A. (2015*). Water Pollution in Baluchistan Province of Pakistan*. *International Journal of Engineering and Applied Sciences*, *2*(6), pp. (89).
- Sardar, K. Maria, S. Noor, J. Shafiqur, R. &Tahir, S. (2012). Drinking water assessment and health risk in district Charssada Pakistan. Journal of Cleaner Production 60 (2013):93-101.
- Sarfarz, M. Nargis, S. Muhammad. (2018). *Groundwater Quality and Health Risk Assessment in Rural Areas of Distric*t Jaffar Abad, Baluchistan (Pakistan). Pakistan journal of Analytical and Environmental Chemistry. Vol. 19(1):79 – 85.
- Terene, J. (1979). Water Supply and Sewerage: International Students (5th ed.). Tokyo, Japan.
- United Nations.(2013). *An increasing demand of water: facts and figures.* http://www.unwater.org/water-cooperation-2013.
- WHO. (1993). Guidelines for drinking water quality. WHO press. (http://www.who.int)
- WHO. (2004). guidelines for drinking water quality. (http://www.who.int).
- Zaigham, H. Najeeb, U. Asmat, U. Sana U. (2015). Ichthyic-Diversity of River Zhob, District Zhob, Baluchistan. Journal of Animal and Plant Sciences 25(3):532-535 ·

ENVIROMENTAL SUSTANIBILITY

A Creative Analysis of Environmental Issues & Global Remedies

Book Blurb

This book delivers an imaginative examination of pressing environmental challenges in the face of evolving climate change. It spans a wide range of topics, addressing global issues and strategies to tackle various aspects, including resource and material management. Furthermore, the book explores how to connect representations in resource analysis to effective management practices.

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